# Eastern Regional Power Committee, Kolkata

**Minutes of Special Meeting on "RGMO/FGMO and PSS Tuning of Generators in Eastern Region" held at ERPC, Kolkata on 31.01.2019 at 11:00 hrs**

List of participants is enclosed at **Annexure-A**.

Member Secretary, ERPC chaired the meeting. He welcomed all the participants in the meeting. He informed that the issue of RGMO/FGMO and PSS Tuning is being reviewed in every OCC Meeting. But there was no significant improvement in the performance of the generators. In order to discuss the issue in detail, in 148th OCC Meeting held on 20.08.2018, it was decided that a separate meeting on Restricted Governor /Free Governor Mode Operation and PSS Tuning of generators with the power station authorities in the Eastern Region shall be convened for detailed deliberation.

He informed that vide CERC order dated 31st July 2017 in Petition No. 84/MP/2015, the Commission directed the following:

Section 23 "

a) Considering the fact that further measures have been put in place to facilitate desirable primary response, the Commission, starting from the month of September, 2017 shall be closely watching the primary response of ISGSs as reported by POSOCO/NLDCs. At the State level, SLDCs shall report the frequency response of intra-State generators to the concerned SERCs.
b) NLDCs and SLDCs through the assistance of POSOCO shall start the process of selecting independent third parties capable of undertaking periodic checkups to monitor the RGMO/FGMO response. To start with, selected independent third parties shall be sent to the generating stations which are not providing the desired RGMO/FGMO response. Independent Third Parties shall ensure that the generator has not, in any way, prevented/disabled the governor from providing the desired response. In case, even after enabling the governors, units are not able to provide the desired response as per the provisions of the Grid Code, third parties, based on the submissions of the generators, shall bring out the technical constraints, if any, which limit the primary response of the units.
c) All ISGSs are directed to provide primary response compulsorily in terms of Regulation 5.2 (f), (g), (h) and (i) of the Grid Code failing which we would not hesitate in initiating action under Section 142 of Electricity Act, 2003 for not providing desired RGMO/FGMO response without any valid reasons. "

Section 24

"….. The Committee (on implementation of FGMO / primary response) has also recommended that there is no requirement for granting any exemption even to LMZ units from operation under RGMO/FGMO with manual intervention."

"… has the option of either expediting the R&M of old units which shall include installation of new EHG governors capable of providing adequate primary response or to go in for retrofit of mechanical governors for adopting RGMO features or to operate on FGMO with manual intervention…"

He advised all the power stations to take the necessary action to improve the performance of the generators.

## I. RGMO/FGMO performance of Generators

ERLDC gave detailed presentation on Primary Response of Generators in the Eastern Regions. The presentation is enclosed at **Annexure-I**.

**During the meeting, the generating stations raised queries pertaining to the following:**

1. Regulatory requirement from the IEGC, CERC orders and Expert Committee recommendations
2. Exemption to old units from providing FGMO / RGMO response

3. Triggering criteria for frequency response, rate/quantum/duration of response
4. Data logging (resolution) and assessment of response

**The queries raised by the generating stations were clarified by ERLDC/ERPC as under:**

1. Primary frequency control is automatic and it aims to arrest the grid frequency variations by automatically varying generator output as per its droop characteristics. Restoration of frequency to the nominal i.e. 50 Hz in case of India is achieved through secondary and tertiary controls ranging from few minutes to hours.
2. Time frame for primary governor control action is of the order of a few seconds i.e. 5- 30 seconds and should last for at least 3-4 minutes to enable secondary control to take over which will allow the primary reserves to be restored. **(Ref: 17.2 of Report of the Committee on Free Governor Mode Operation of Generating Units, Ref: Chapter 4, Page 34 of Report of Expert Group to review and suggest measures for bringing power system operation closer to National Reference Frequency).**
3. IEGC permits a ripple filter of 0.03 Hz. This implies that the unit shall provide primary response whenever the change in frequency is more than 0.03 Hz. The time between two successive frequency measurements shall be suitably tuned to provide primary response within 5-30 seconds of the grid event causing the change in frequency. **(Ref : IEGC 5.2(f))**
4. After the automatic primary response the unit may be brought back to its scheduled load at the rate of 1% per minute though local supplementary control. (**Ref: IEGC 5.2(i))**
5. The ex-bus schedule shall be restricted to MCR less normative auxiliary consumption. Operation in Valve wide-open mode is prohibited. The control valves shall be kept throttled to provide governor response at all times. (**Ref: IEGC 5.2(h))**
6. No exemption has been granted by CEC to LMZ units for operation under RGMO/FGMO. In case of difficulty to operate in RGMO, generators may operate under FGMO with manual intervention for providing mandated response as per the provisions of the Grid Code. (**Ref: CERC order in Petition No. 65/MP/2014, Ref: CERC order in Petition No. 84/MP/2015,Ref: 19.9 of Report of the Committee on Free Governor Mode Operation of Generating Units)**.
7. The methodology used for computing the Frequency Response Characteristics shall be as per the procedure approved by Hon'ble CERC vides order dated 3rd May 2013. All generators as well HVDC were advised to calculate their response as per the described procedure during the meeting.(**Ref: CERC order in Petition No. 47/MP/2012**). SLDCs were advisedto report the frequencyresponse of intra-State generators to the concerned SERCs. (**Ref: CERC order in Petition No. 84/MP/2015).**
8. A generator response which is minimum 40% of ideal FRC is to be considered as adequate response. **(Ref: 9.6 (b) of Report of Expert Group to review and suggest measures for bringing power system operation closer to National Reference Frequency).**
9. The MW and frequency data available at station DCS shall be archived at a resolution of at least 1 second, for post-facto analysis of the adequacy of the response.

All the station representatives stated that the gap in understanding the provisions of the grid code had been addressed through the deliberations in the meeting. They assured that the governor settings would be re-tuned in the next few days to provide the response expected as per the IEGC 5$^{th}$ amendment. All the generating utilities updated the latest status and their action plan which is enclosed at **Annexure-IA**.

The two frequency response events, which occurred in the month of January 2019, were also informed by ERLDC to all generators. It was decided that all generators would submit high resolution (1 sec) data of MW output, Frequency (Hz), and RGMO influence in MW (if available) along with FRC calculation and suitable explanation of response by 4$^{th}$ Feb 2019 to erldcprotection@posoco.in and erpcprotection@gmail.com.

**Events Date and Time:**

| Date and Time | Time period for required data | Event | Frequency Drop |
|---|---|---|---|
| 16-01-2019 12:25 hrs | 12:24 hrs to 12:29 hrs | Solar Generation loss in Northern region of 1400 MW | 0.107 Hz |
| 23-01-2019 06:37 Hrs | 06:36 hrs to 06:41 hrs | Loss of generation at Rampur & NJPC in Northern region | 0.08 Hz |

After detailed deliberation, the following decisions were taken in the meeting:

1. All the generators would take necessary tuning of their units along with the Boiler logic to provide adequate RGMO/FGMO response
2. Generator which cannot provide automatic response should operate on FGMO with manual intervention
3. All the generators would address the issues related to implementation of RGMO/FGMO during R & M works immediately.
4. All the generators shall calculate the RGMO/FGMO response for the events informed by ERLDC.
5. All the generators shall submit the high resolution data to SLDC and ERLDC for computation of the response.
6. The status of implementation of RGMO/FGMO and the performance of the generators shall be reviewed in monthly OCC Meetings.

II. **PSS Tuning of Generators**

ERLDC gave a detailed presentation on role of Power System Stabilizer and the importance of its tuning. Presentation is enclosed at **Annexure-II**. ERLDC explained the following during the PSS Tuning Session:

1. Low frequency oscillation and its adverse effect on the grid as well generating plants
2. Basics of PSS tuning, PSS Tuning Requirement as per Regulation/Standards
3. Criteria for PSS tuning and analysis of PSS tuning.
4. Exciter, PSS Data and its tuning details as received from various generators **(Annexure-II A)**
5. Analysis of PSS tuning field reports submitted by the various generators **(Annexure-II B)**
6. Need for Model data submission from generators and its utilization

After detailed deliberation, the following decisions were taken in the meeting:

1. Generators who had already done the PSS tuning shall submit the details of the Excitation System, PSS tuning and its report as per the list attached at **Annexure-II A**. The generators shall submit the Generator terminal voltage, Field voltage, Real power, Reactive Power, Generator Speed, and PSS output in excel/.csv format for better analysis of the result.
2. Generators for which PSS tuning was not carried out shall take up the PSS Tuning with OEM immediately
3. Generators for which PSS was not in service shall take up the issue with OEM immediately to bring the PSS into service.
4. For any future tuning, it was recommended to all generators to collect the response along with data in .csv/excel format.
5. All the generators where the PSS tuning was done and PSS not in service shall submit their action plan for PSS Tuning in line with IEGC and CEA standards before the next OCC meeting to ERPC/ERLDC.

Meeting ended with vote of thanks to the chair.

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Annexure-A

**Participants in Special Meeting on "RGMO/FGMO and PSS Tuning of Generators in Eastern Region"**

Venue: ERPC Conference Hall, Kolkata Time: 11:00 hrs Date: 31.01.2019 (Thursday)

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Annexure-I

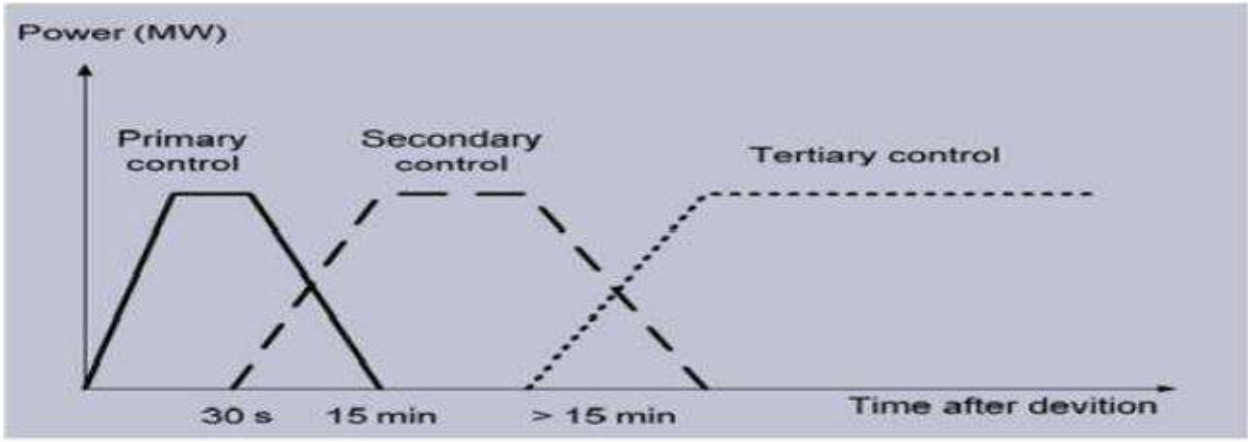
# Primary Response of Generators in the Eastern Regions

**Raj Protim Kundu**
**ERLDC, POSOCO**

# Frequency Control

- To arrest change in frequency, control actions are required
- Frequency Control can be divided into three overlapping windows of time
  - Primary Frequency Control
  - Secondary Frequency Control (AGC)
  - Tertiary Frequency Control

Before all types of control, grid inertia comes into action



# IEGC Regulations: RGMO / FGMO

➢IEGC 5.2 (f)

- ***All Coal/lignite based thermal generating units of 200 MW and above, Open Cycle Gas Turbine/Combined Cycle generating stations having gas turbines of capacity more than 50 MW each and all hydro units (with more than 3 hour pondage) of 25 MW and above" which are synchronized with the grid, irrespective of their ownership, shall have their governors in operation at all times….***

- ***The restricted governor mode of operation shall essentially have the following features:***

  ***a) There should not be any reduction in generation in case of improvement in grid frequency below 50.00 Hz (for example, if grid frequency changes from 49.9 to 49.95 Hz or from 49.95 to 49.99 Hz , there shall not be any reduction in generation). For any fall in grid frequency, generation from the unit should increase as per generator droop upto a maximum of 5% of the generation subject to ceiling limit of 105 % of the MCR of the unit subject to machine capability.***

  ***b) Ripple filter of +/- 0.03 Hz. shall be provided so that small changes in frequency are ignored for load correction, in order to prevent governor hunting.***

  ***c) If any of these generating units is required to be operated without its governor in operation as specified above, the RLDC shall be immediately advised about the reason and duration of such operation.***

***All governors shall have a droop setting of between 3% and 6%.***

# IEGC Regulations: RGMO / FGMO

- IEGC 5.2 (g)
  - ***Facilities available with/in load limiters, Automatic Turbine Run-up System (ATRS), Turbine supervisory control, coordinated control system, etc., shall not be used to suppress the normal governor action in any manner and no dead bands and/or time delays shall be deliberately introduced….***
- IEGC 5.2 (h)
  - ***All Coal/Lignite based thermal generating units of 200 MW and above, Open Cycle Turbine/Combine Cycle generating station having gas turbines of more than 50 MW each and all hydro units of 25 MW and above operating at or up to 100% of their Maximum Continuous Rating (MCR) shall have the capability of (and shall not in any way be prevented from) instantaneously picking up to 105%, 105% and 110% of their MCR, respectively, when the frequency falls suddenly.”***
  - ***After an increase in generation as above, a generating unit may ramp back to the original level at a rate of about one per cent (1%) per minute, in case continued operation at the increased level is not sustainable.***

# IEGC Regulations: RGMO / FGMO

- IEGC 5.2 (h)
  - ***For the purpose of ensuring primary response, RLDCs/SLDCs shall not schedule the generating station or unit (s) thereof beyond ex-bus generation corresponding to 100% of the Installed capacity of the generating station or unit(s) thereof. The generating station shall not resort to Valve Wide Open (VWO) operation of units whether running on full load or part load, and shall ensure that there is margin available for providing Governor action as primary response.***
- IEGC 5.2 (i)
  - ***The recommended rate for changing the governor setting, i.e., supplementary control for increasing or decreasing the output (generation level) for all generating units, irrespective of their type and size, would be one (1.0) per cent per minute or as per manufacturer's limits.***

# IEGC Regulations: Primary Response Testing

- IEGC 5.2 (g)
  - ***Facilities available with/in load limiters, Automatic Turbine Run-up System (ATRS), Turbine supervisory control, coordinated control system, etc., shall not be used to suppress the normal governor action in any manner and no dead bands and/or time delays shall be deliberately introduced except as specified in para 5.2(f) above.***
  - ***Provided that periodic check-ups by third party should be conducted at regular interval once in two years through independent agencies selected by RLDCs or SLDCs as the case may be. The cost of such test s shall be recovered by the RLDCs or SLDCs from the Generators. If deemed necessary by RLDCs/SLDCs, the test may be conducted more than once in two years.***

In Fifth Amendment of IEGC regulation

# CERC order in Petition No. 84/MP/2015, Date of order: July 31, 2017

- Clause 23 (a):
  - *"… the Commission, starting from the month of **September, 2017** shall be closely watching the **primary response of ISGSs** as reported by POSOCO/NLDCs.*
  - *At the State level, **SLDCs** shall report the frequency response of **intra-State generators** to the **concerned SERCs**."*
- Clause 23(b)
  - "… SLDCs through the assistance of POSOCO shall start the process of selecting independent third parties capable of undertaking periodic check-ups to monitor the RGMO/FGMO response.
  - To start with selected independent third parties shall be sent to the generating stations which are not providing the desired RGMO/FGMO response…."

# CERC order in Petition No. 84/MP/2015, Date of order: July 31, 2017

- Clause 23(b)
  - *"…Independent Third Parties shall **ensure** that the generator **has not, in any way, prevented/disabled the governor from providing the desired response**.*
  - *In case, **even after enabling the governors**, units are **not able to provide the desired response** as per the provisions of the Grid Code, third parties, based on the submissions of the generators, shall **bring out the technical constraints,** if any, which limit the primary response of the units."*
- Clause 23(c)
  - *"All **ISGSs** are directed to **provide primary response compulsorily** in terms of Regulation 5.2 (f), (g), (h) and (i) of the Grid Code **failing which** we would not hesitate in **initiating action under Section 142** of Electricity Act, 2003 for not providing desired RGMO/FGMO response without any valid reasons."*

# CERC order in Petition No. 84/MP/2015, Date of order: July 31, 2017

- Clause 24
  - *"….. The Committee (on implementation of FGMO / primary response) has also recommended that **there is no requirement for granting any exemption even to LMZ units** from operation under RGMO/FGMO with manual intervention*
  - *… has the **option** of either expediting the R&M of old units which shall include **installation of new EHG governors** capable of providing adequate primary response or*
  - *to go in for **retrofit of mechanical governors** for adopting RGMO features or*
  - *to operate on **FGMO with manual intervention**…"*

# Desired Primary Frequency Control Action

- Governor response is desired for arresting fall/rise in frequency as per droop characteristics.
- Time frame for primary governor control action is of the order of a few seconds i.e. 5-30 seconds.
- Governor actions should last for at least 3-4 minutes.

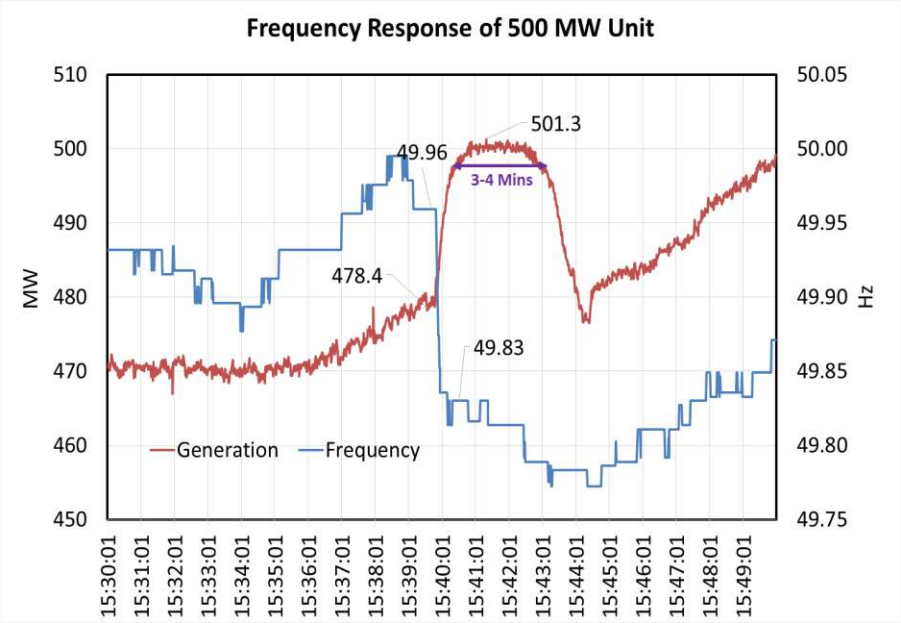
Quote

- ***"Commission, revised IEGC which was notified to be effective from 01.04.2006 and essentially modified the requirement of holding the increased / decreased generation level by Governor Action for 5 minutes and allowed the return of the machine to the original load at a slow rate of 1% per minute."***

Unquote

**Report of the Committee on Free Governor Mode Operation of Generating Units**

# What is Adequate Governor Frequency Respons




**Delta f = 0.13 Hz**

**Droop = 5% , MCR = 500 MW**

**Ideal Response = (0.13/50) x (100/5) x 500 = 26 MW**

**Actual response = 22.9 MW = Delta P observed**

**Actual response as % of Ideal Response = 88 %**

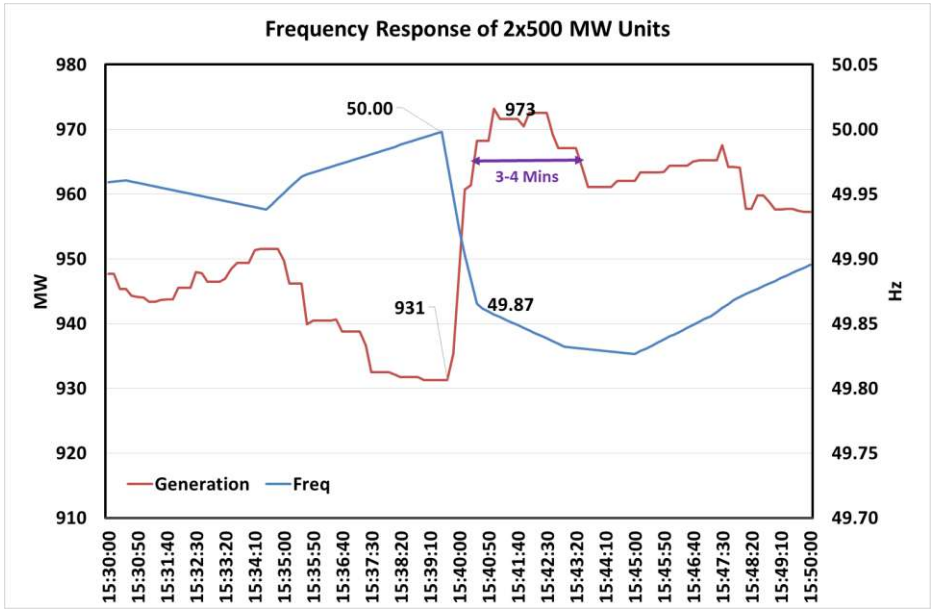
**Delta f = 0.13 Hz**

**Droop = 5% , MCR = 1000 MW**

**Ideal Response = (0.13/50) x (100/5) x 1000=52 MW**

**Actual response = 42 MW = Delta P observed**

**Actual response as % of Ideal Response = 80 %**



# Frequency Response Characteristics of the System

Reflects ability of the system to respond to deviation in frequency

$$Frequency\ Response\ Characteristics = \frac{(P_B - P_A) - P_L}{f_B - f_A}\ MW/Hz$$

$P_A$ – Actual Net interchange of control area before the event
(+ve for import and – ve for export)

$P_B$ – Actual Net interchange of control area after the event
(+ve for import and – ve for export)

$f_B$ – frequency after the Event

$f_A$ – frequency before the Event

$P_L$ – Load or Generation lost by Control Area

$P_L$ is +Ve for Generation loss,
$P_L$ is –Ve for load loss

As per Clause 23 (a) of CERC order in Petition No. 84/MP/2015, SLDCs to report the frequency response of intra-State generators to the concerned SERCs

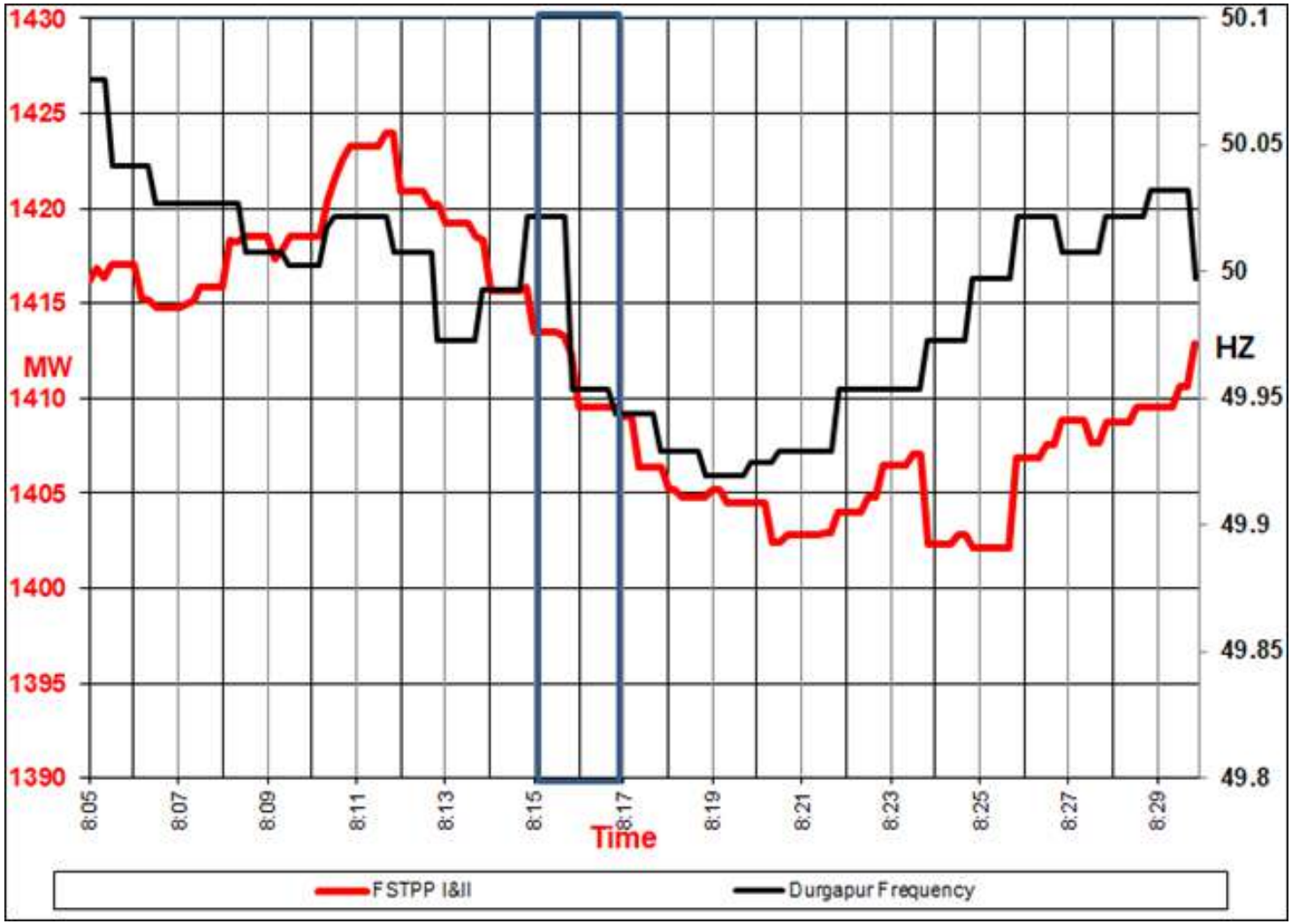
# Response observed at generators at Eastern Region

| Event No | Event Description | Date | Time | Net Frequency Change |
|---|---|---|---|---|
| 1 | 3090 MW generation loss at Kotra | 23-04-18 | 10:42 | 0.287 Hz Dip |
| 2 | 1100 MW generation loss at Lalitpur | 06-05-18 | 16:50 | 0.055 Hz Dip |
| 3 | 900 MW generation loss at Andal | 10-06-18 | 06:11 | 0.054 Hz Dip |
| 4 | 1025 MW generation loss in Sikkim | 10-07-18 | 08:14 | 0.062 Hz Dip |
| 5 | 1060 MW generation loss in Sikkim | 30-07-18 | 20:48 | 0.071 Hz Dip |
| 6 | 1300 MW load loss in Maharastra | 06-08-18 | 13:06 | 0.13 Hz rise |
| 7 | 890 MW generation loss at KSK | 07-08-18 | 14:17 | 0.035 Hz Dip |
| 8 | 1200 MW generation loss at Rampur | 29-08-18 | 04:02 | 0.056 Hz Dip |
| 9 | 2400 MW generation loss at Mundra | 30-10-18 | 19:23 | 0.19 Hz Dip |
| 10 | 1400 MW solar generation loss in Rajasthan | 16-01-19 | 12:25 | 0.05 Hz Dip |

# Farakka I & II

| Event No | Date | Time | Frequency Change | Farakka-I & II generation Change after the Event (As per ERLDC SCADA in MW) | Actual response as % of Ideal Response (Assuming 5 % Droop) |
|---|---|---|---|---|---|
| Event-1 | 23-04-18 | 10:42 | 0.287 Hz Dip | -1.5 | -4 % |
| Event-2 | 06-05-18 | 16:50 | 0.055 Hz Dip | -1.13 | -7% |
| Event-3 | 10-05-18 | 06:11 | 0.054 Hz Dip | 3.21 | 16% |
| Event-4 | 10-07-18 | 08:14 | 0.062 Hz Dip | -3.89 | -11 % |
| Event-5 | 30-07-18 | 20:48 | 0.071 Hz Dip | 0.5 | 1 % |
| Event-6 | 06-08-18 | 13:06 | 0.13 Hz Rise | -3.37 | 18 % |
| Event-7 | 07-08-18 | 14:17 | 0.035 Hz Dip | 2.87 | 17 % |
| Event-8 | 29-08-18 | 04:02 | 0.056 Hz Dip | 1.01 | 2% |
| Event-9 | 30-10-18 | 19:23 | 0.19 Hz Dip | 5.75 | 8 % |
| Event-10 | 16-01-19 | 12:25 | 0.05 Hz Dip | 10.8 | 43.3% |

# Farakka I & II response on 10th July 2018 at 08:14 h

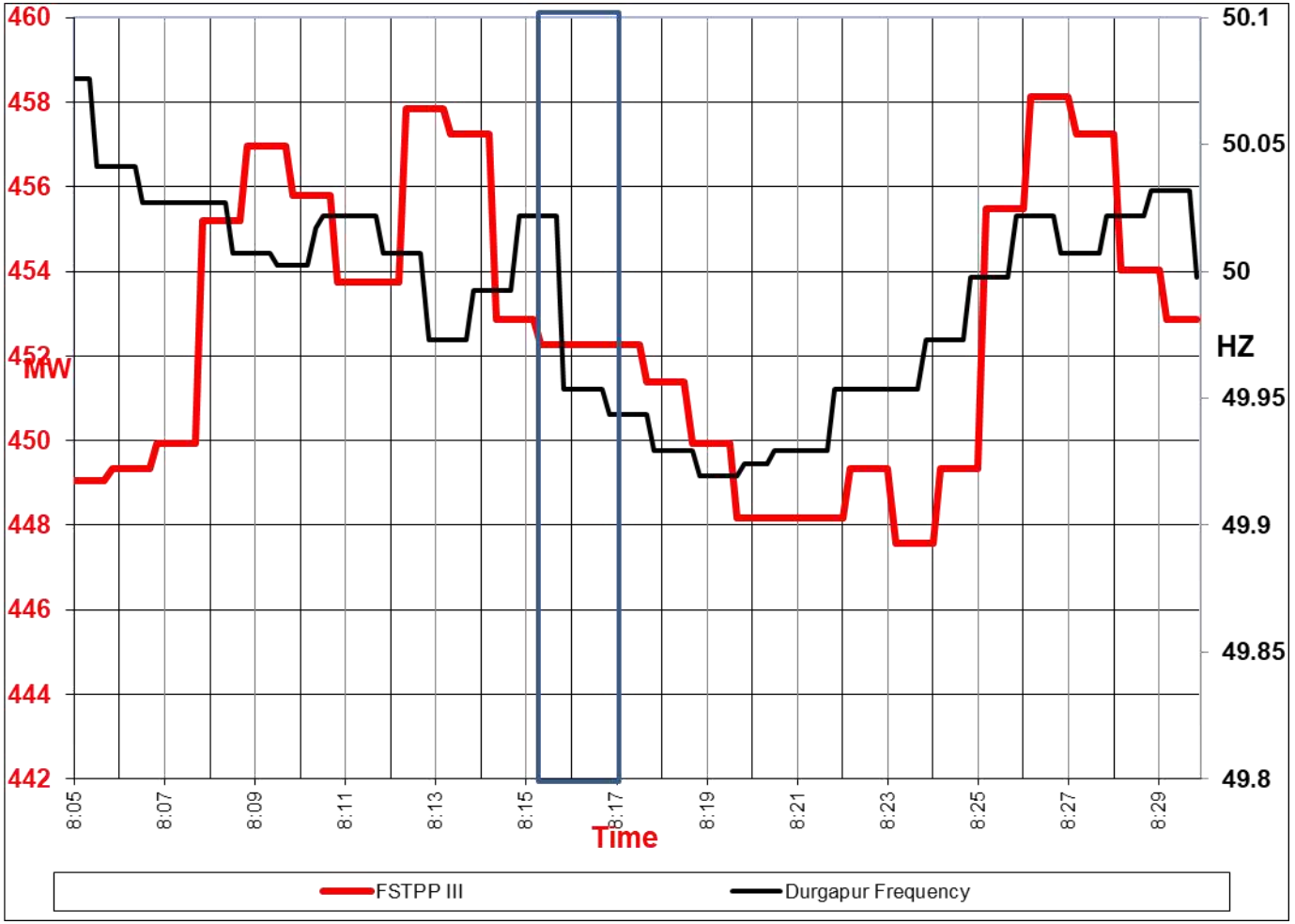



* Based on ERLDC SCADA data

# Farakka III

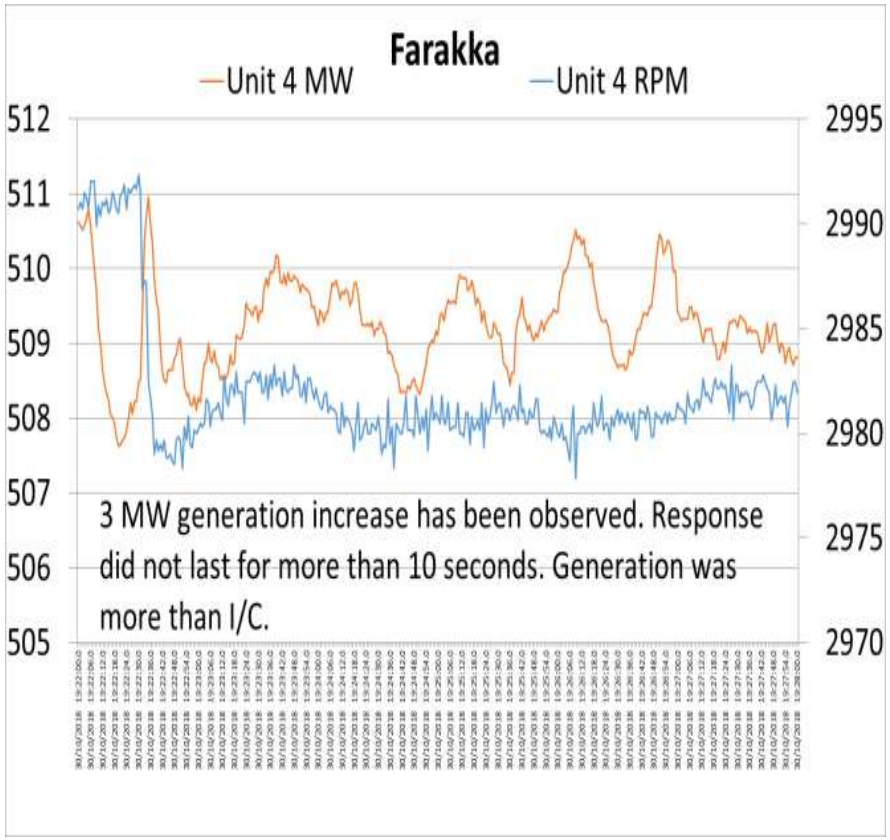
| Event No | Date | Time | Frequency Change | Farakka-III MW Change after the Event (As per ERLDC SCADA) | Actual response as % of Ideal Response (Assuming 5 % Droop) |
|---|---|---|---|---|---|
| Event-1 | 23-04-18 | 10:42 | 0.287 Hz Dip | -3.5 | -6.8% |
| Event-2 | 06-05-18 | 16:50 | 0.055 Hz Dip | 0 | 0% |
| Event-3 | 10-05-18 | 06:11 | 0.054 Hz Dip | 0 | 0% |
| Event-4 | 10-07-18 | 08:14 | 0.062 Hz Dip | -0.6 | -5.2% |
| Event-5 | 30-07-18 | 20:48 | 0.071 Hz Dip | 9.7 | 78% |
| Event-6 | 06-08-18 | 13:06 | 0.13 Hz Rise | -1.5 | 23.5% |
| Event-7 | 07-08-18 | 14:17 | 0.035 Hz Dip | 0 | 0% |
| Event-8 | 29-08-18 | 04:02 | 0.056 Hz Dip | -0.9 | -8.6% |
| Event-9 | 30-10-18 | 19:23 | 0.19 Hz Dip | 7.9 | 22.8% |
| Event-10 | 16-01-19 | 12:25 | 0.05 Hz Dip | 1.2 | 13.4% |

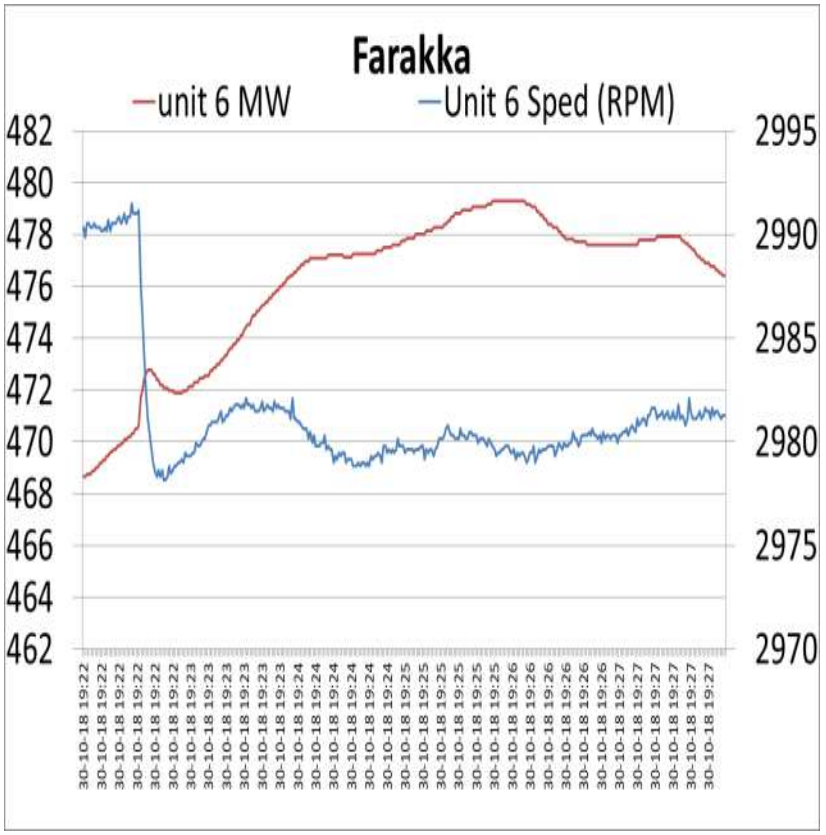
# Farakka III response on 10th July 2018 at 08:14 hrs




* Based on ERLDC SCADA data

# Farakka unit 4 & 6 response on 30th October 2018 at 19:23 hrs



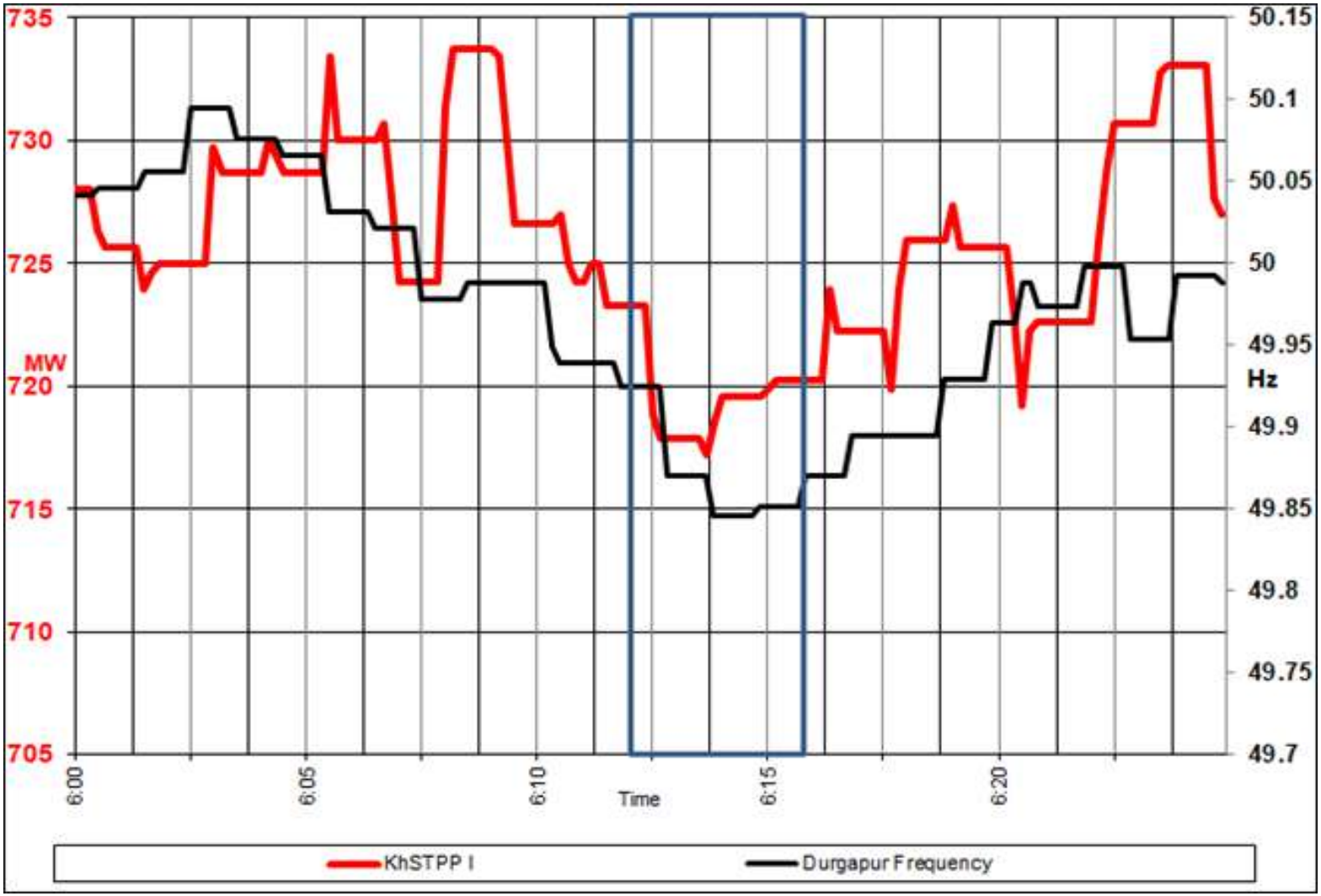

**RGMO was out of service for unit 1, 2 & 3 and unit 5 was out of service**

* Based on data received from Farakka

# KhSTPP - I

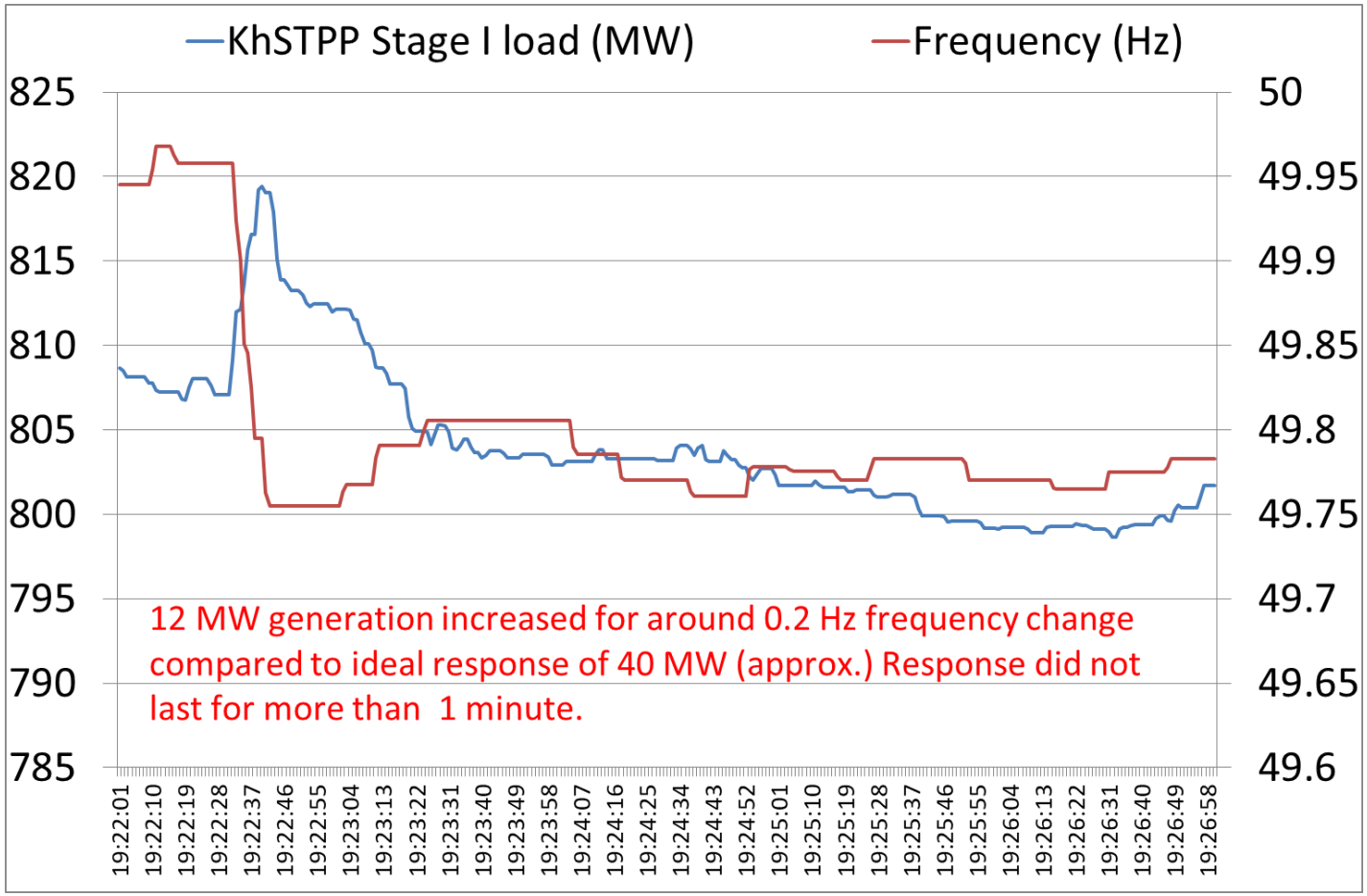
| Event No | Date | Time | Frequency Change | Kahalgaon-I generation Change after the Event (As per ERLDC SCADA in MW) | Actual response as % of Ideal Response (Assuming 5 % Droop) |
|---|---|---|---|---|---|
| Event-1 | 23-04-18 | 10:42 | 0.287 Hz Dip | 28 | 114 % |
| Event-2 | 06-05-18 | 16:50 | 0.055 Hz Dip | -1.35 | - 9 % |
| Event-3 | 10-05-18 | 06:11 | 0.054 Hz Dip | -5.4 | -35 % |
| Event-4 | 10-07-18 | 08:14 | 0.062 Hz Dip | 0 | 0 % |
| Event-5 | 30-07-18 | 20:48 | 0.071 Hz Dip | -2.6 | -16 % |
| Event-6 | 06-08-18 | 13:06 | 0.13 Hz Rise | 3.38 | -35 % |
| Event-7 | 07-08-18 | 14:17 | 0.035 Hz Dip | 23.34 | 270 % |
| Event-8 | 29-08-18 | 04:02 | 0.056 Hz Dip | -19 | - 61 % |
| Event-9 | 30-10-18 | 19:23 | 0.19 Hz Dip | -3.72 | -10 % |
| Event-10 | 16-01-19 | 12:25 | 0.05 Hz Dip | 5.4 | 39.2% |

# KhSTPP – I response on 10th May 2018 at 06:11 hrs



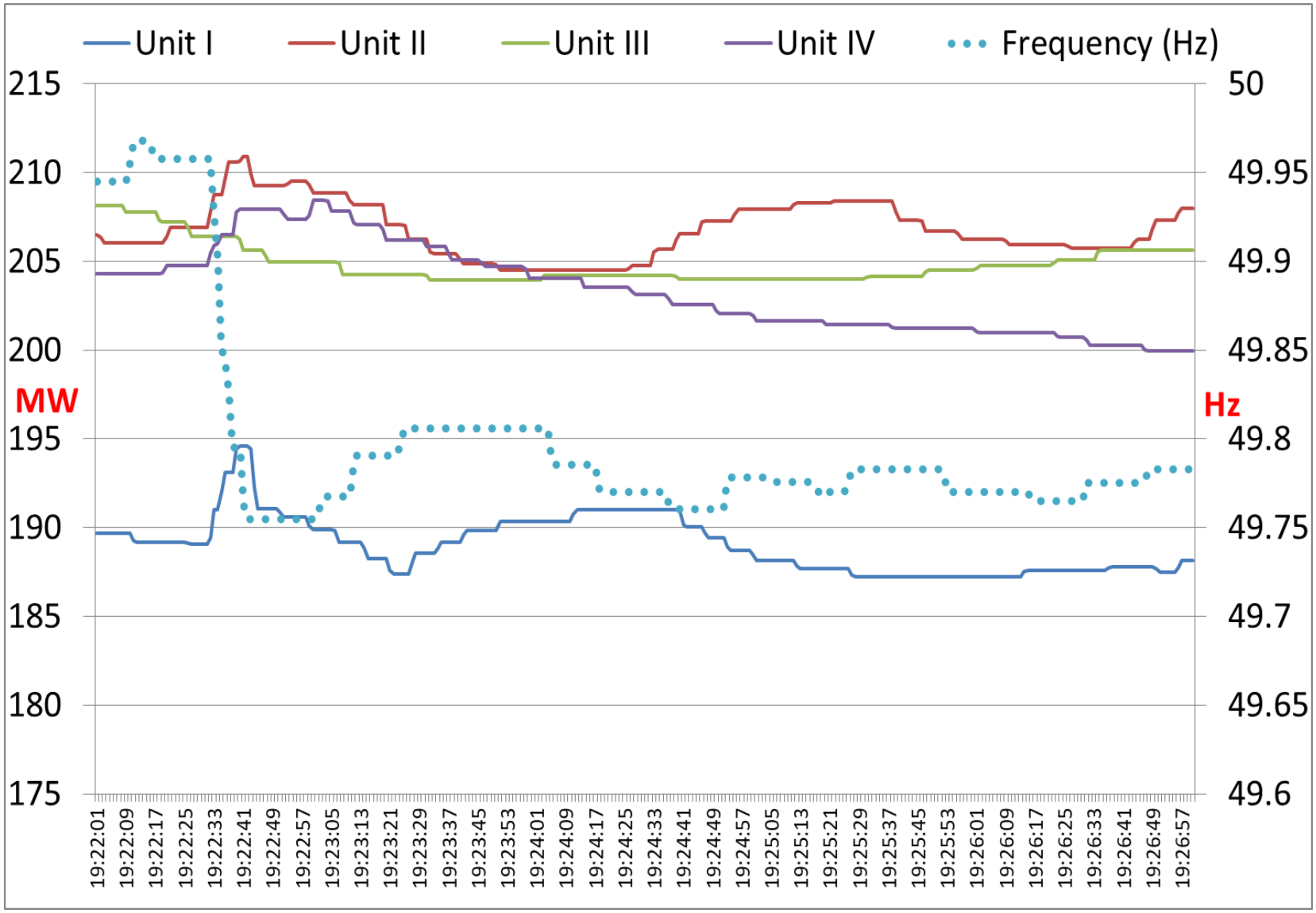

* Based on ERLDC SCADA data

# KhSTPP – I response on 30th October 2018 at 19:23 hrs




* Based on data received from KhSTPP

# KhSTPP – I response on 30th October 2018 at 19:23 hrs

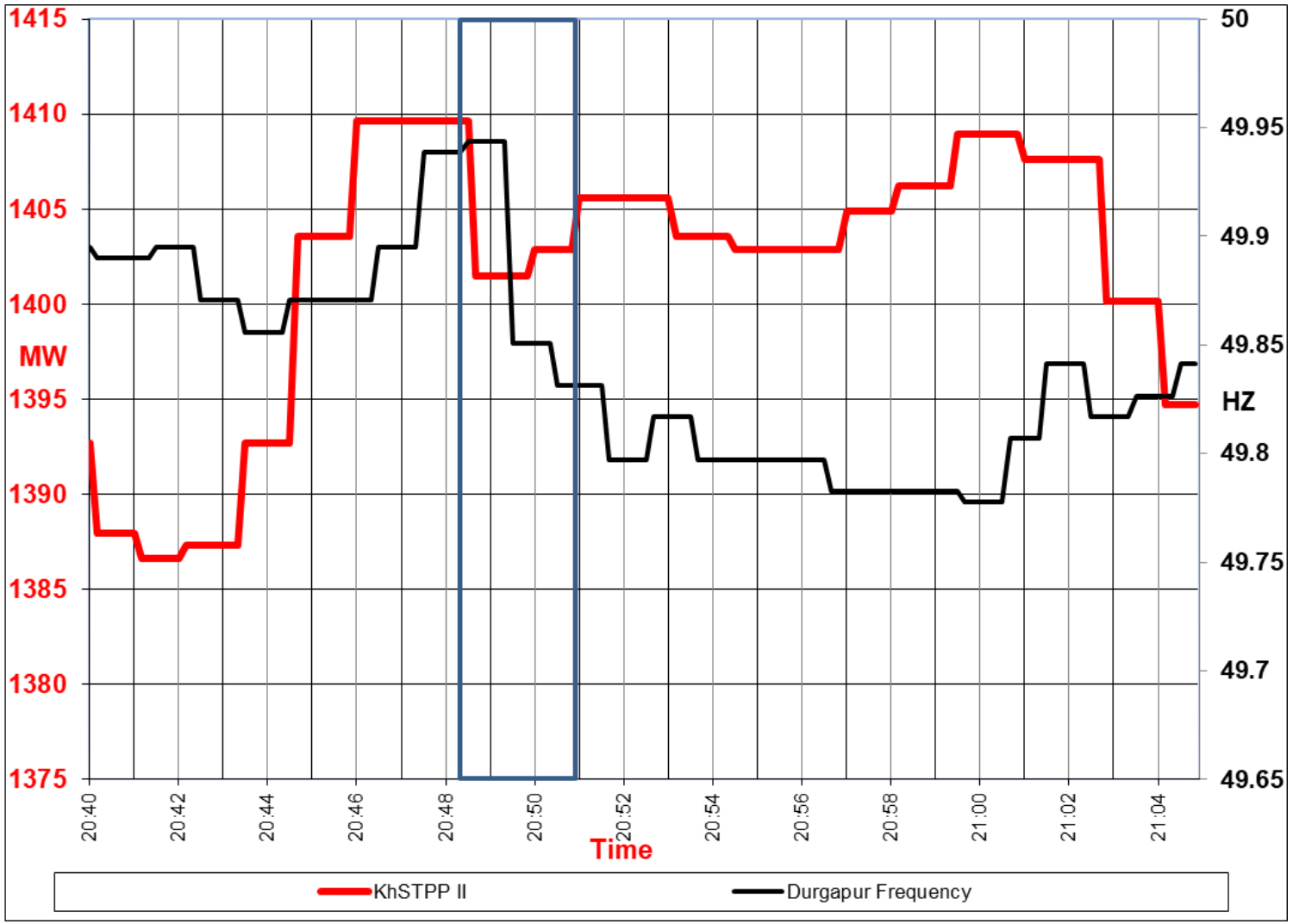



* Based on data received from KhSTPP

# KhSTPP - II

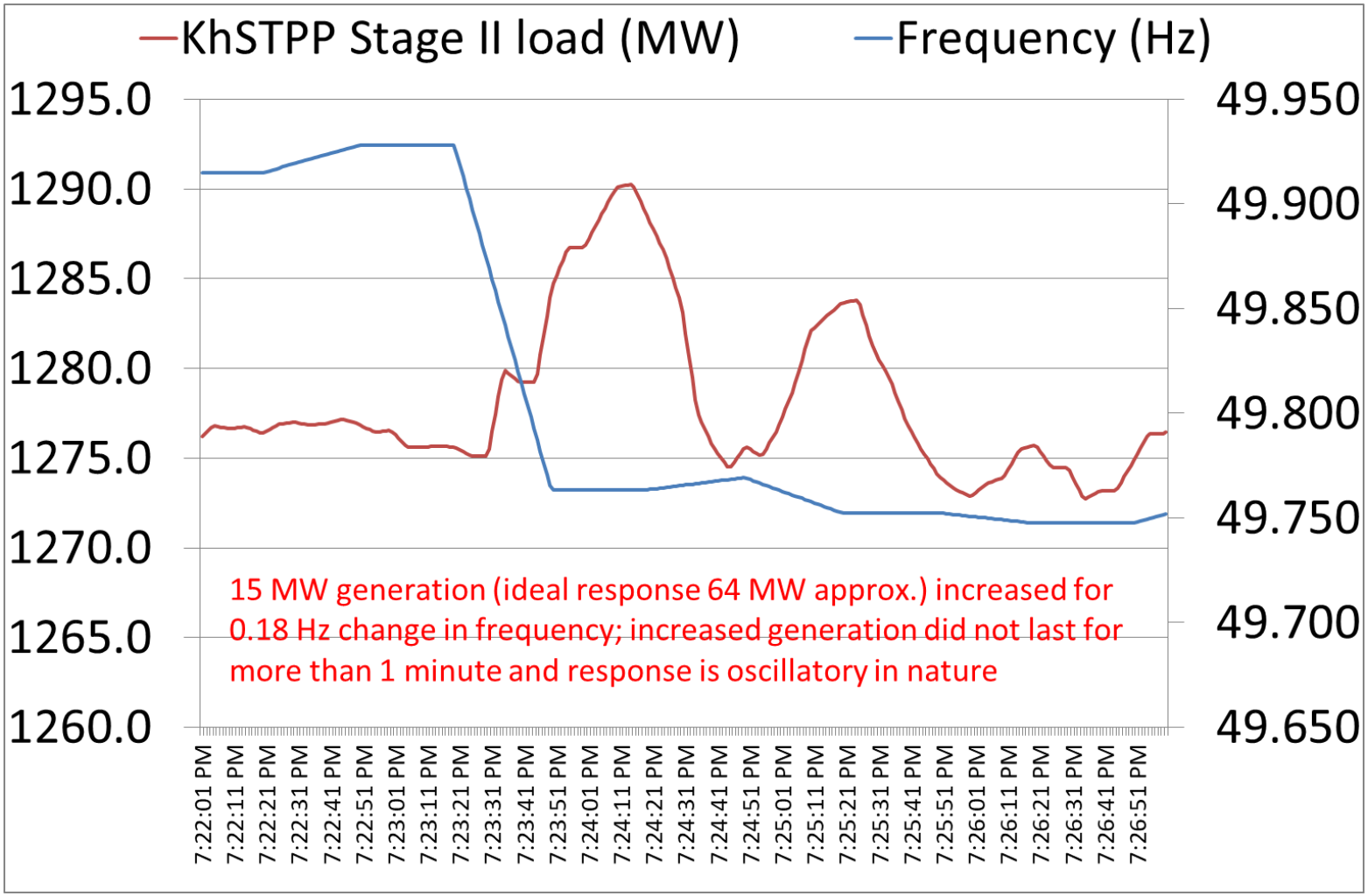
| Event No | Date | Time | Frequency Change | Kahalgaon-II MW Change after the Event (As per ERLDC SCADA) | Actual response as % of Ideal Response (Assuming 5 % Droop) |
|---|---|---|---|---|---|
| Event-1 | 23-04-18 | 10:42 | 0.287 Hz Dip | 0 | 0% |
| Event-2 | 06-05-18 | 16:50 | 0.055 Hz Dip | 2 | 7.8% |
| Event-3 | 10-05-18 | 06:11 | 0.054 Hz Dip | 6.8 | 22% |
| Event-4 | 10-07-18 | 08:14 | 0.062 Hz Dip | 2 | 8.8% |
| Event-5 | 30-07-18 | 20:48 | 0.071 Hz Dip | -6.8 | -16.9% |
| Event-6 | 06-08-18 | 13:06 | 0.13 Hz Rise | -2.7 | 14.5% |
| Event-7 | 07-08-18 | 14:17 | 0.035 Hz Dip | 2.7 | 13.9 |
| Event-8 | 29-08-18 | 04:02 | 0.056 Hz Dip | 4.1 | 12.9% |
| Event-9 | 30-10-18 | 19:23 | 0.19 Hz Dip | 0 | 0% |
| Event-10 | 16-01-19 | 12:25 | 0.05 Hz Dip | 2 | 7.8% |

# KhSTPP – II response on 30th July 2018 at 20:48 hrs



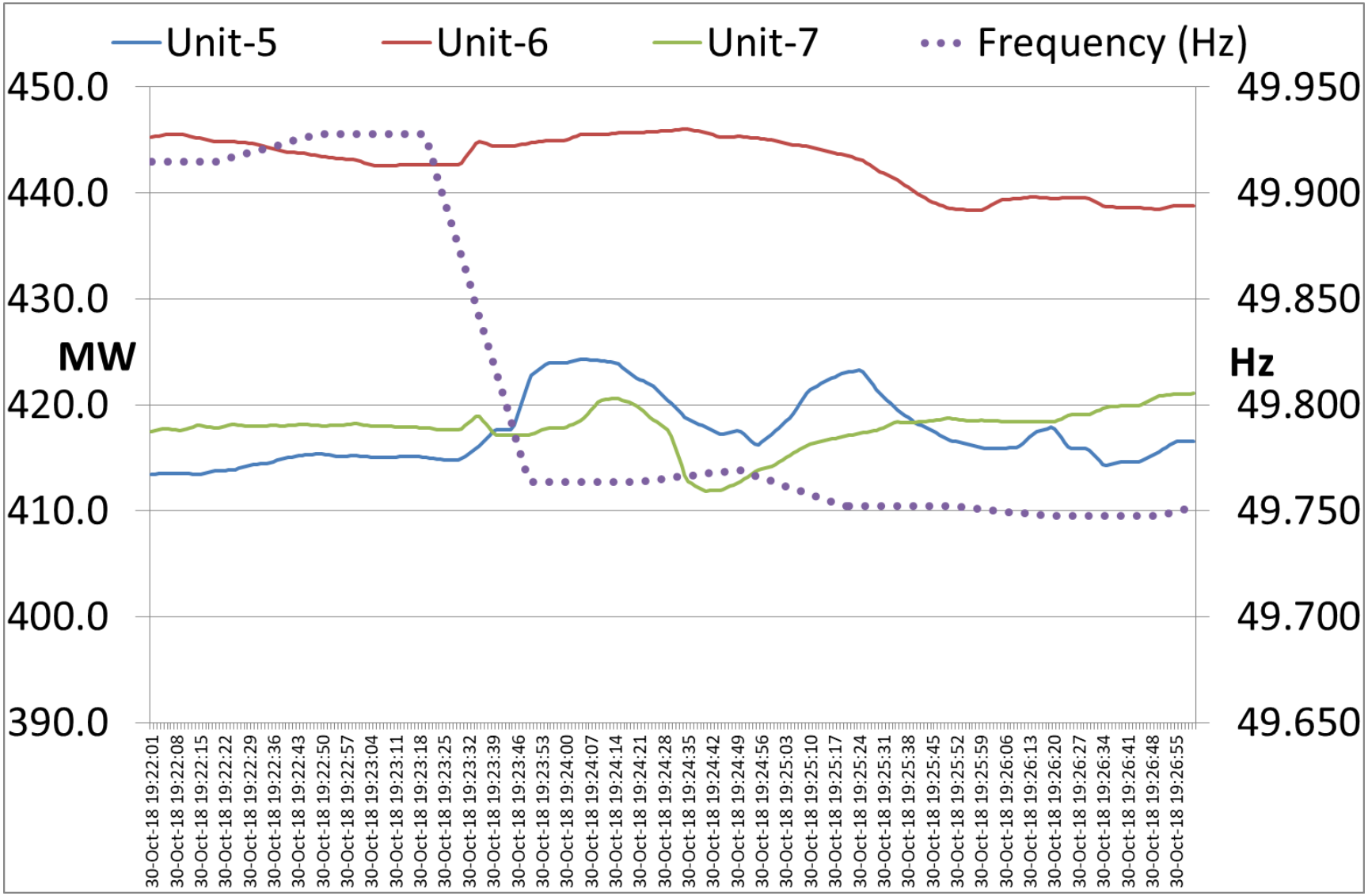

* Based on ERLDC SCADA data

# KhSTPP – II response on 30th October 2018 at 19:23 hrs




* Based on data received from KhSTPP

# KhSTPP – II response on 30th October 2018 at 19:23 hrs

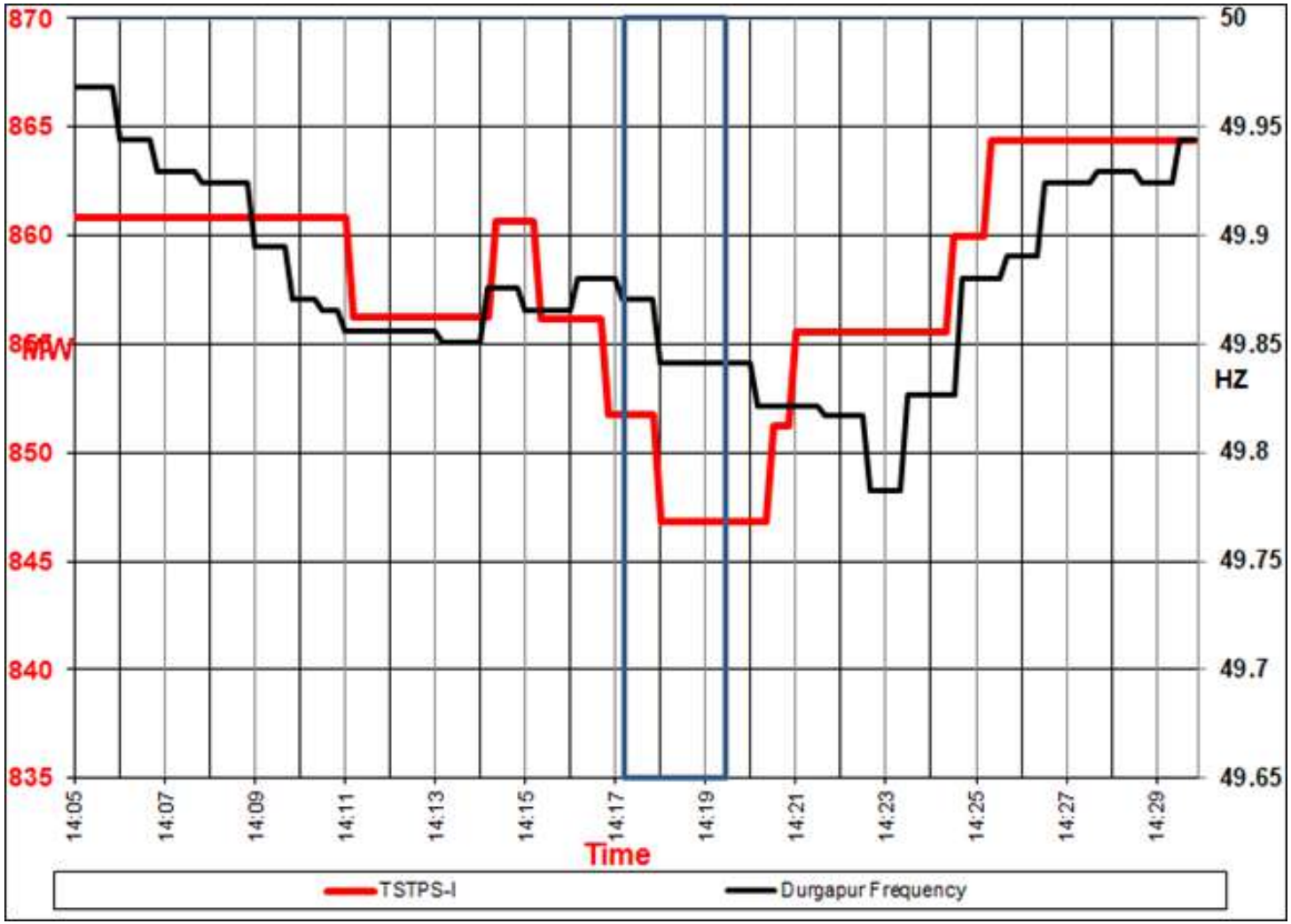



* Based on data received from KhSTPP

# TSTPP - I

| Event No | Date | Time | Frequency Change | Talcher Stg I generation Change after the Event (As per ERLDC SCADA in MW) | Actual response as % of Ideal Response (Assuming 5 % Droop) |
|---|---|---|---|---|---|
| Event-1 | 23-04-18 | 10:42 | 0.287 Hz Dip | -5.5 | -12 % |
| Event-2 | 06-05-18 | 16:50 | 0.055 Hz Dip | 4.78 | 28 % |
| Event-3 | 10-05-18 | 06:11 | 0.054 Hz Dip | 8.2 | 42 % |
| Event-4 | 10-07-18 | 08:14 | 0.062 Hz Dip | 4 | 22 % |
| Event-5 | 30-07-18 | 20:48 | 0.071 Hz Dip | 0 | 0 % |
| Event-6 | 06-08-18 | 13:06 | 0.13 Hz Rise | 0 | 0 % |
| Event-7 | 07-08-18 | 14:17 | 0.035 Hz Dip | -4.96 | -42 % |
| Event-8 | 29-08-18 | 04:02 | 0.056 Hz Dip | 0 | 0 % |
| Event-9 | 30-10-18 | 19:23 | 0.19 Hz Dip | 0 | 0 % |
| Event-10 | 16-01-19 | 12:25 | 0.05 Hz Dip | 0 | 0% |

# TSTPP – I response on 07th August 2018 at 14:17 hr

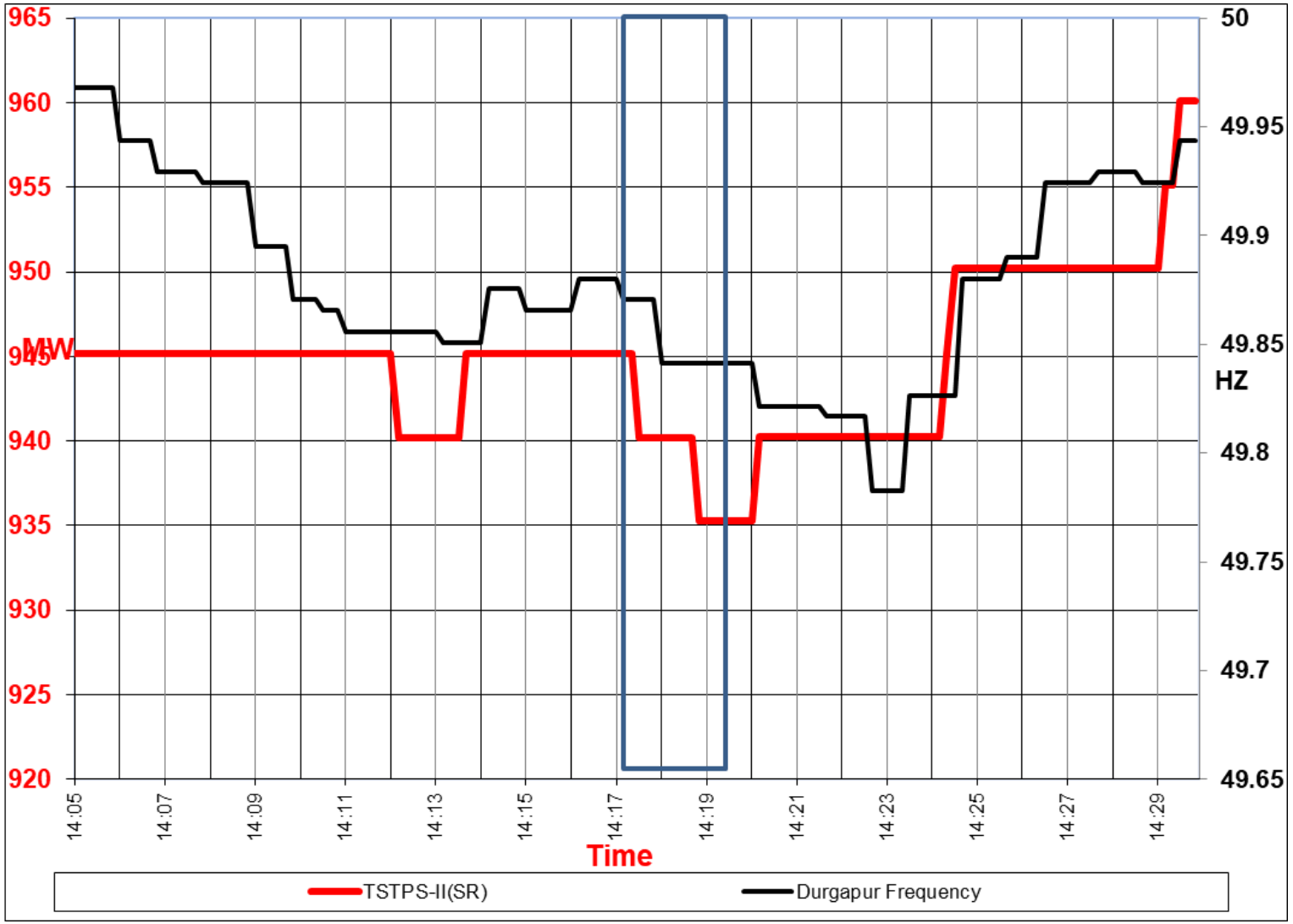



* Based on ERLDC SCADA data

# TSTPP - II

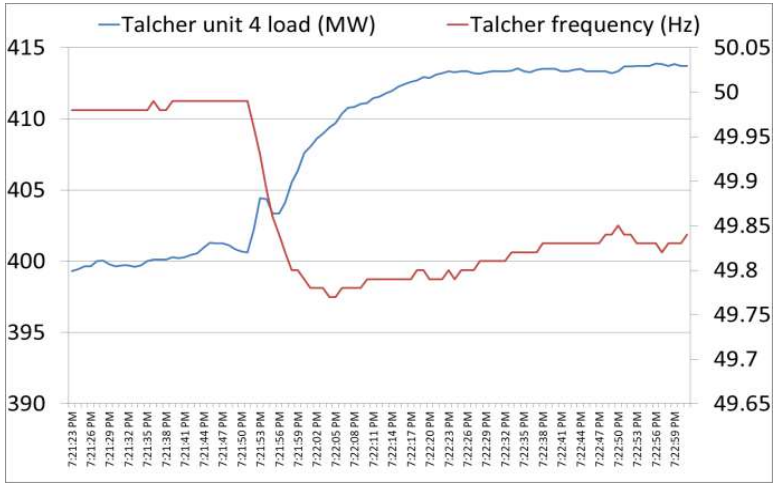
| Event No | Date | Time | Frequency Change | Talcher Stg II MW Change after the Event (As per ERLDC SCADA) | Actual response as % of Ideal Response (Assuming 5 % Droop) |
|---|---|---|---|---|---|
| Event-1 | 23-04-18 | 10:42 | 0.287 Hz Dip | 21.9 | 10.1% |
| Event-2 | 06-05-18 | 16:50 | 0.055 Hz Dip | 10.7 | 25.6% |
| Event-3 | 10-05-18 | 06:11 | 0.054 Hz Dip | -10.5 | -25.6% |
| Event-4 | 10-07-18 | 08:14 | 0.062 Hz Dip | 3.8 | 14.5% |
| Event-5 | 30-07-18 | 20:48 | 0.071 Hz Dip | 3.9 | 9.1% |
| Event-6 | 06-08-18 | 13:06 | 0.13 Hz Rise | -0.4 | 1.1% |
| Event-7 | 07-08-18 | 14:17 | 0.035 Hz Dip | 7.9 | 35.8% |
| Event-8 | 29-08-18 | 04:02 | 0.056 Hz Dip | 1.6 | 6.4% |
| Event-9 | 30-10-18 | 19:23 | 0.19 Hz Dip | Data not available | -- |
| Event-10 | 16-01-19 | 12:25 | 0.05 Hz Dip | 5.46 | 57% |

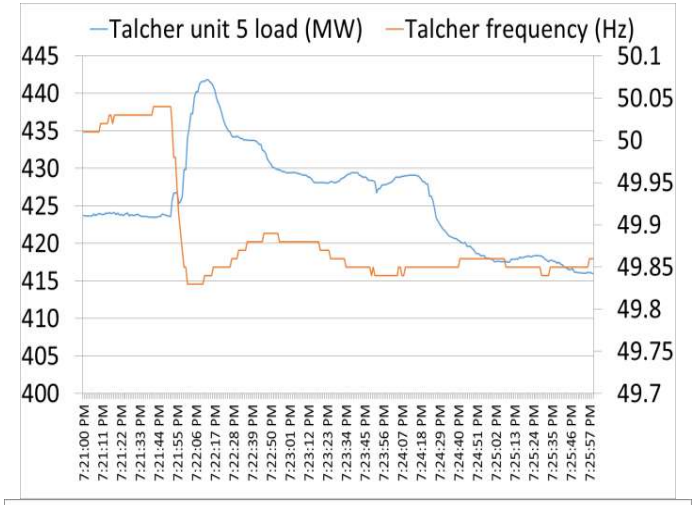
# TSTPP – II response on 07th August 2018 at 14:17 h

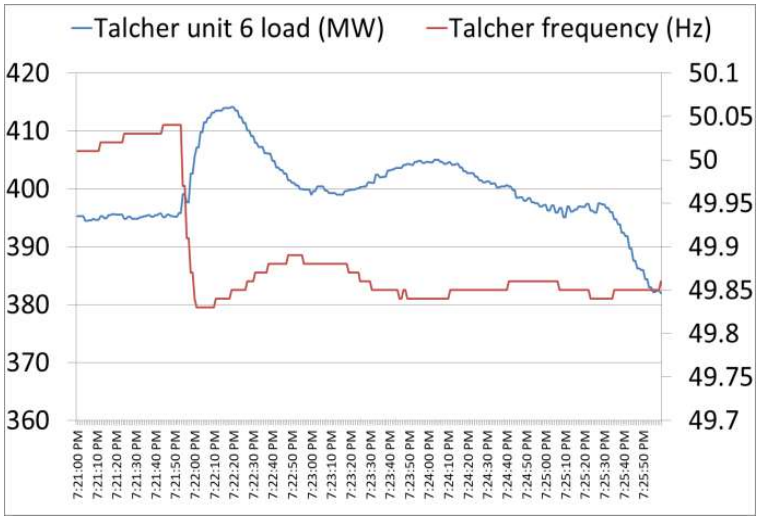


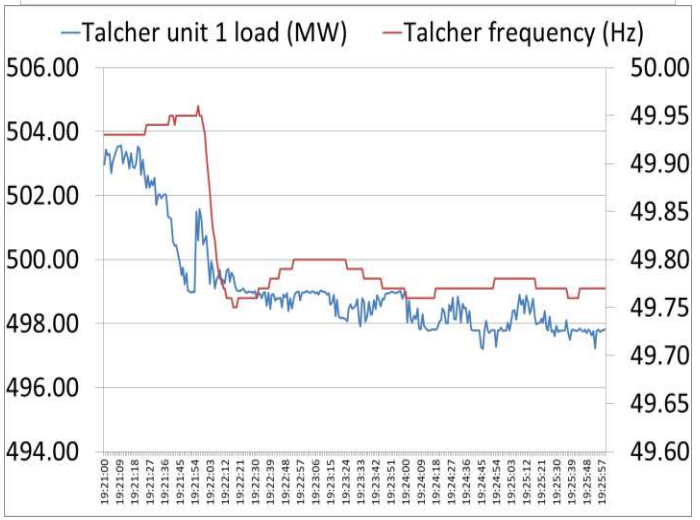

* Based on ERLDC SCADA data

# TSTPP response on 30th October 2018 at 19:23 hrs



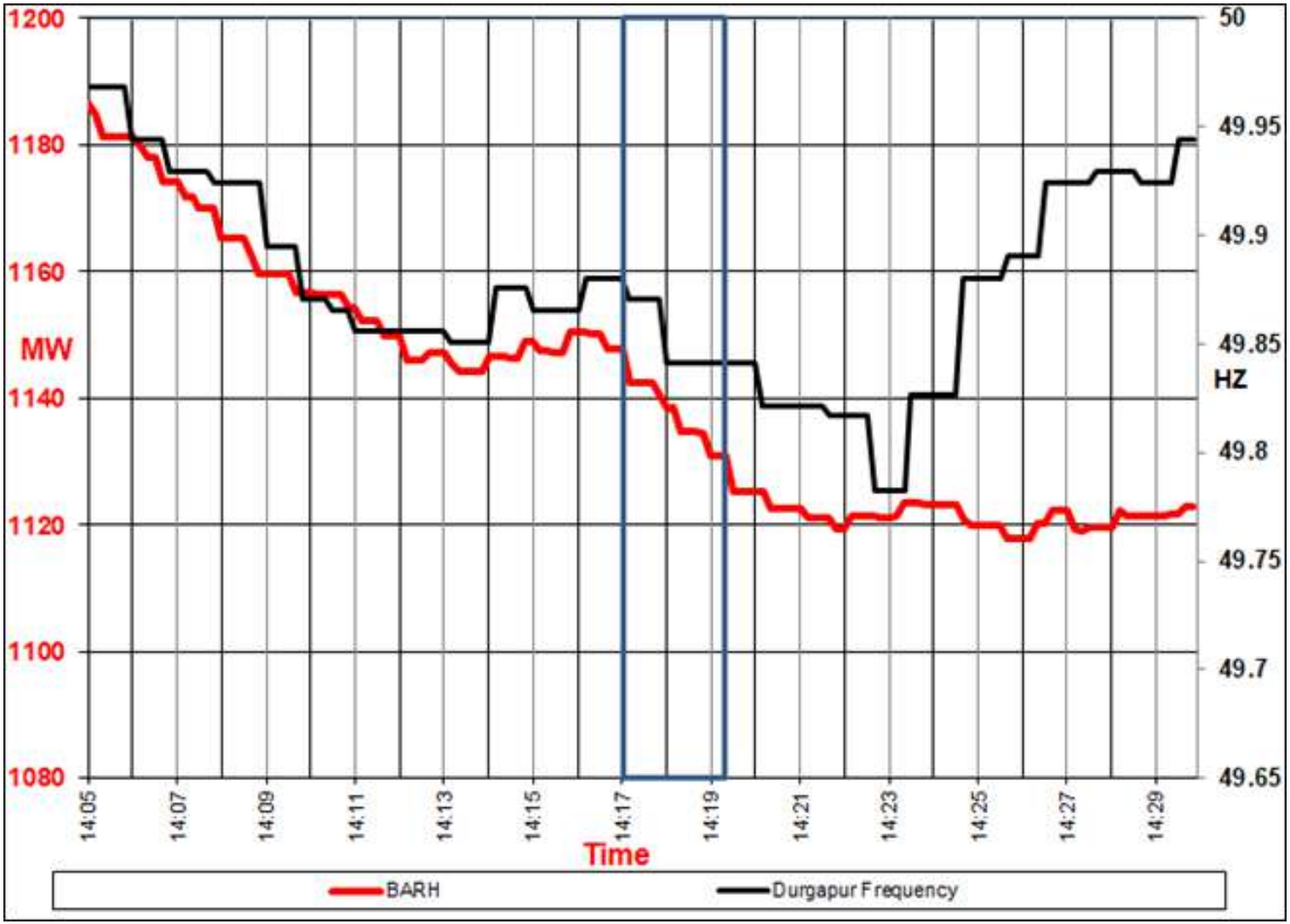

Unit 2 & 3 were out of service

* Based on data received from TSTPP

# Barh

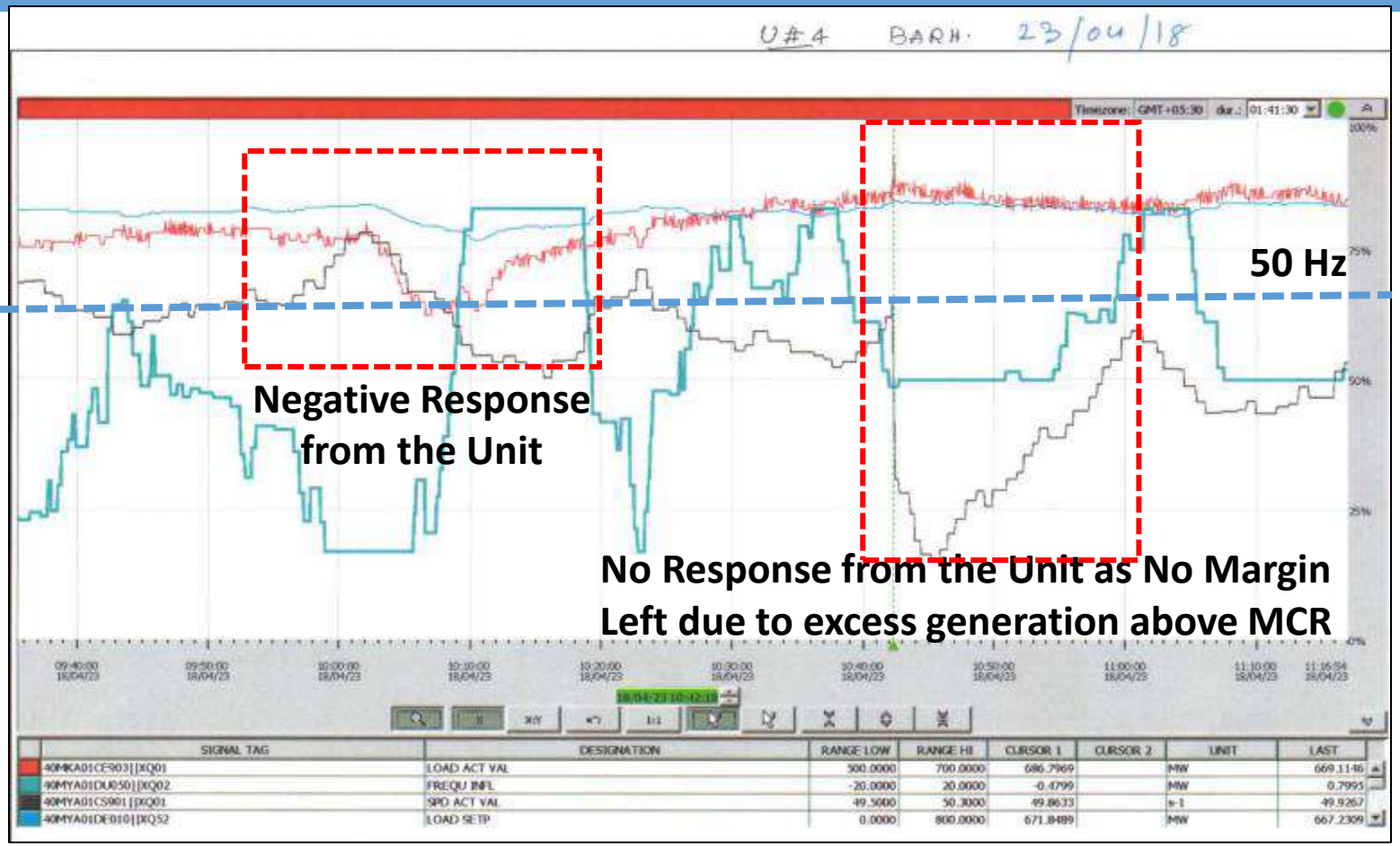
| Event No | Date | Time | Frequency Change | Barh generation Change after the Event(As per ERLDC SCADA) | Actual response as % of Ideal Response(Assuming 5 % Droop) |
|---|---|---|---|---|---|
| Event-1 | 23-04-18 | 10:42 | 0.287 Hz Dip | 2.82 | 4 % |
| Event-2 | 06-05-18 | 16:50 | 0.055 Hz Dip | -1.1 | -4 % |
| Event-3 | 10-05-18 | 06:11 | 0.054 Hz Dip | Data not Updating at ERLDC | Data not Updating at ERLDC |
| Event-4 | 10-07-18 | 08:14 | 0.062 Hz Dip | Data not Updating at ERLDC | Data not Updating at ERLDC |
| Event-5 | 30-07-18 | 20:48 | 0.071 Hz Dip | 0.169 | 0 % |
| Event-6 | 06-08-18 | 13:06 | 0.13 Hz Rise | - 6.4 (Ramp Down in Units going on) | 27 % |
| Event-7 | 07-08-18 | 14:17 | 0.035 Hz Dip | - 9.35 (Ramp Down in Units going on) | -58 % |
| Event-8 | 29-08-18 | 04:02 | 0.056 Hz Dip | - 0.23 | -1 % |
| Event-9 | 30-10-18 | 19:23 | 0.19 Hz Dip | 2.75 | 4 % |
| Event-10 | 16-01-19 | 12:25 | 0.05 Hz Dip | -0.2 | -0.7% |

# Barh response on 07th August 2018 at 14:17 hrs




* Based on ERLDC SCADA data

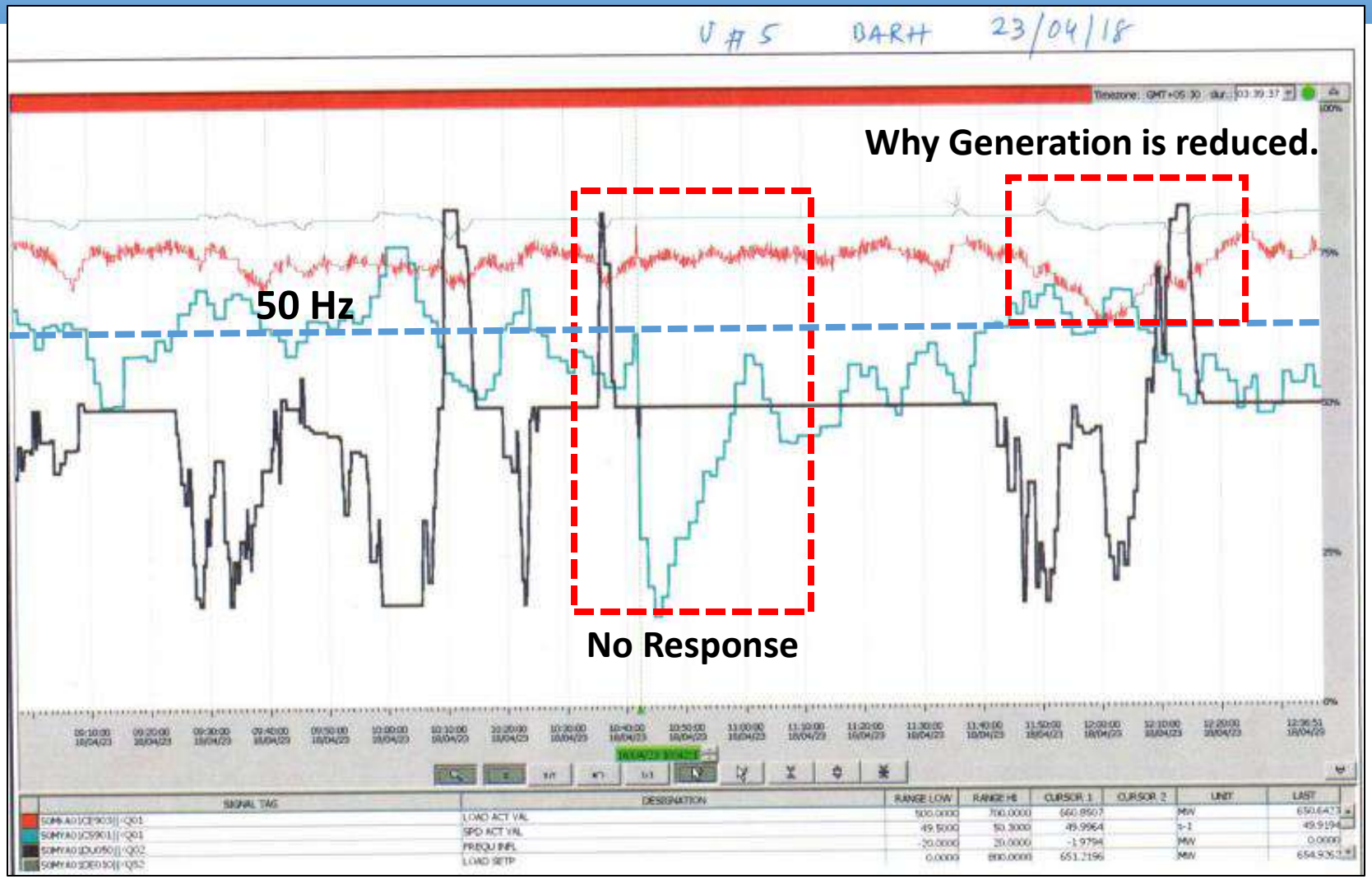
# Barh Unit 4 Response for Event at 10:42 on 23-04-18




* Based on data received from Barh

- **No Response from The Unit 4 as it was generating 673 MW (Installed Capacity 660 MW)**
- **Margin for RGMO Response is not there.**

# Barh Unit 5 Response for Event at 10:42 on 23-04-18



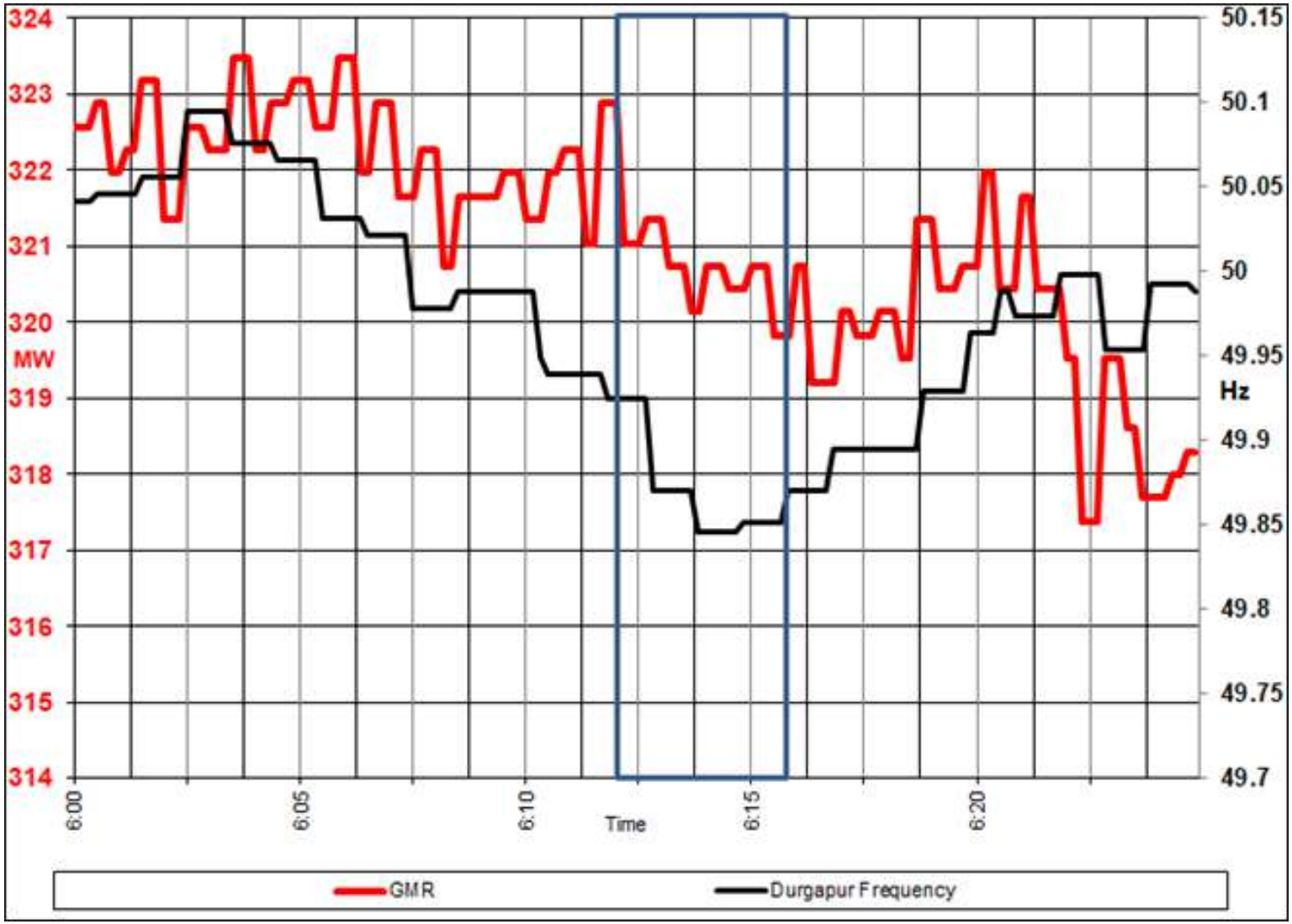

- **No Response from The Unit 5.**
- **Generation reduction observed when the frequency fall is not sharp and that to not Primary reponse.**

* Based on data received from Barh

# GMR

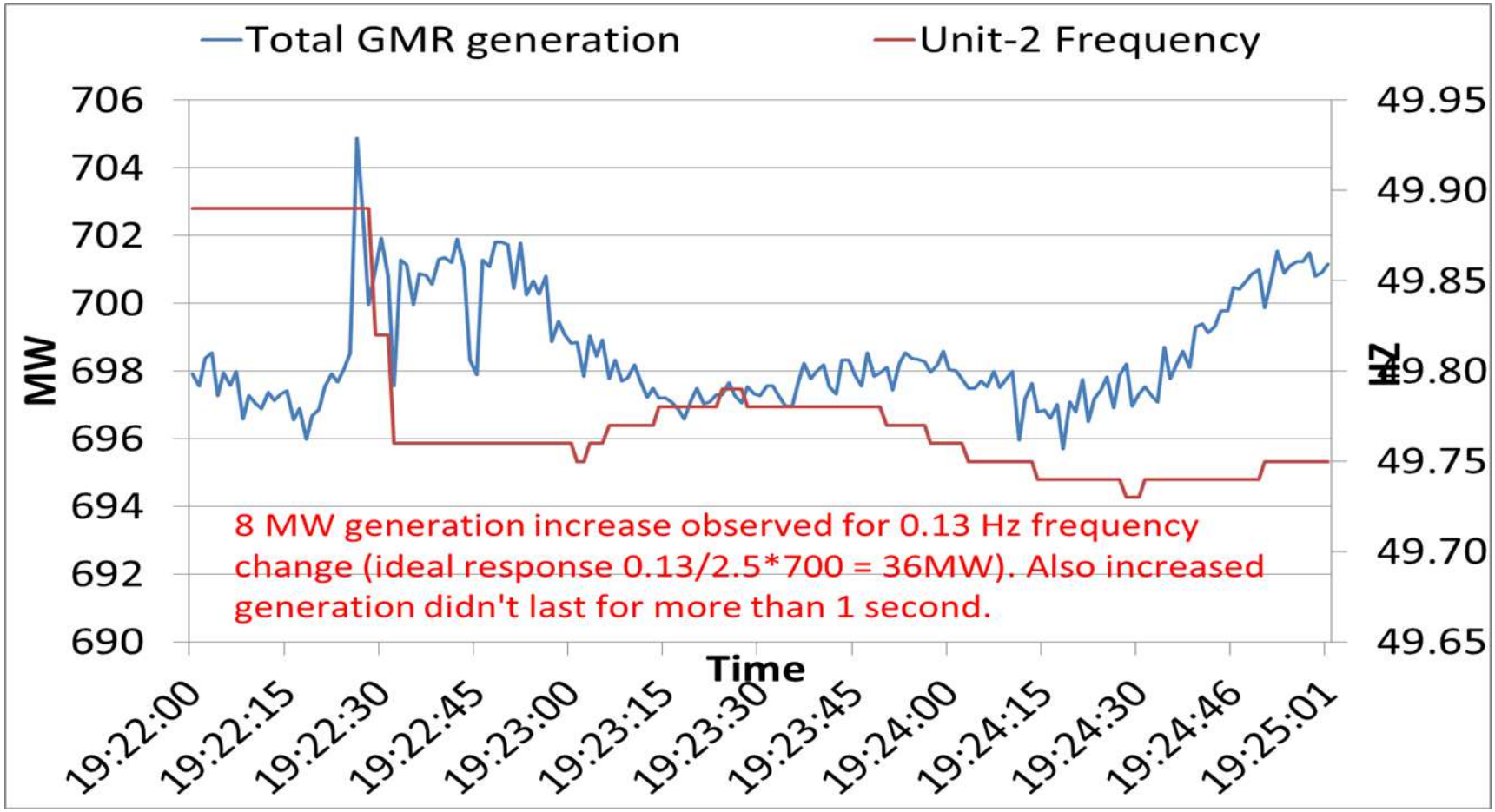
| Event No | Date | Time | Frequency Change | GMR generation Change after the Event (As per ERLDC SCADA in MW) | Actual response as % of Ideal Response (Assuming 5 % Droop) |
|---|---|---|---|---|---|
| Event-1 | 23-04-18 | 10:42 | 0.287 Hz Dip | 10( Slow Response) | 32 % |
| Event-2 | 06-05-18 | 16:50 | 0.055 Hz Dip | 6.7(Slow Response) | 61 % |
| Event-3 | 10-05-18 | 06:11 | 0.054 Hz Dip | -1.5 | -22 % |
| Event-4 | 10-07-18 | 08:14 | 0.062 Hz Dip | Data Not Updating | Data Not Updating |
| Event-5 | 30-07-18 | 20:48 | 0.071 Hz Dip | 1.83 (Unit Was Ramping) | 20 % |
| Event-6 | 06-08-18 | 13:06 | 0.13 Hz Rise | -0.91 | 9 % |
| Event-7 | 07-08-18 | 14:17 | 0.035 Hz Dip | 6.11 (Unit Was Ramping) | 78 % |
| Event-8 | 29-08-18 | 04:02 | 0.056 Hz Dip | 24 (Unit Was Ramping) | 195 % |
| Event-9 | 30-10-18 | 19:23 | 0.19 Hz Dip | -4.2 | -13 % |
| Event-10 | 16-01-19 | 12:25 | 0.05 Hz Dip | -2.1 | 36.4% |

# GMR response on 10th May 2018 at 06:11 hrs




* Based on ERLDC SCADA data

# GMR response on 30th October 2018 at 19:23 hrs

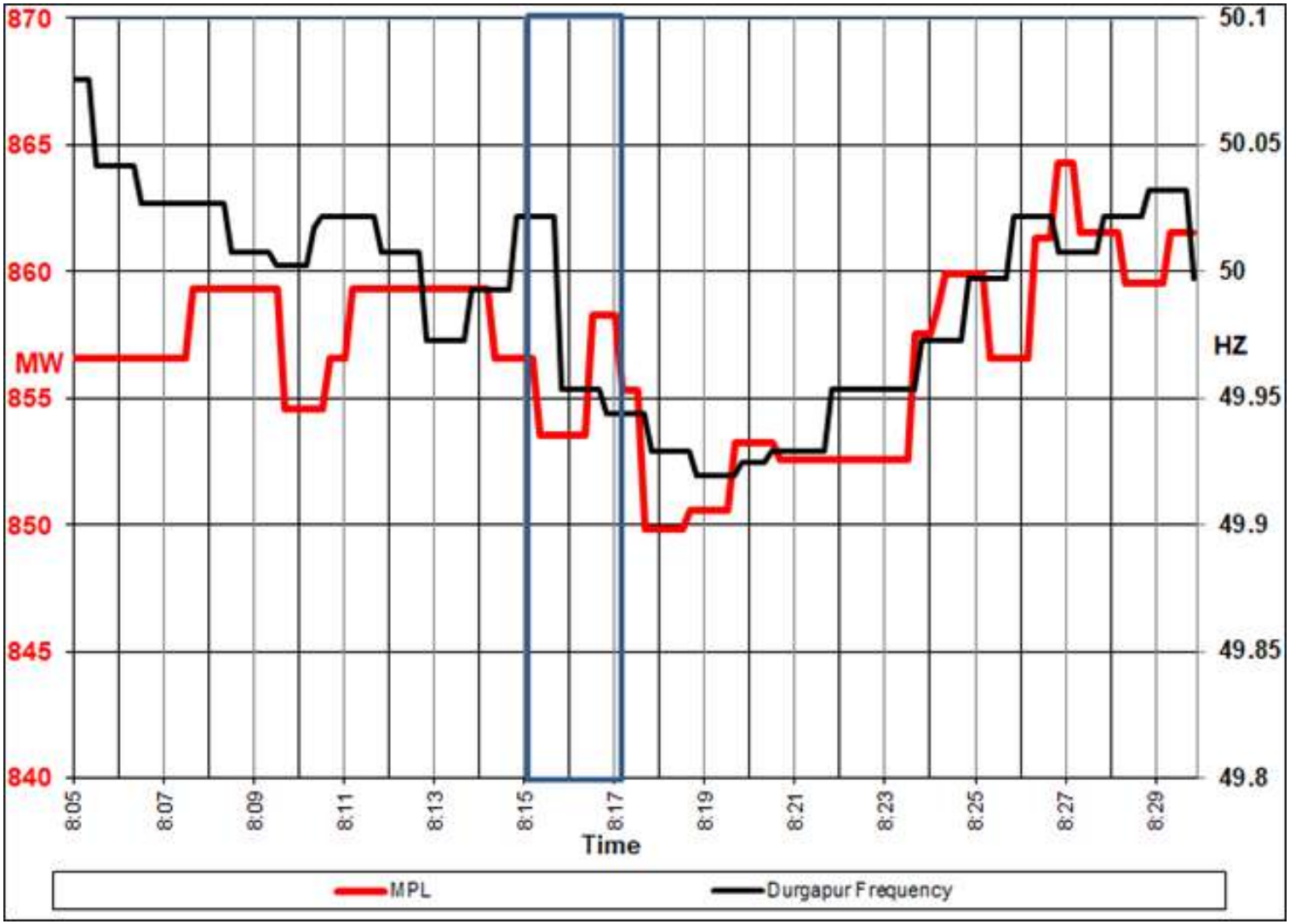



* Based on data received from GMR

# MPL

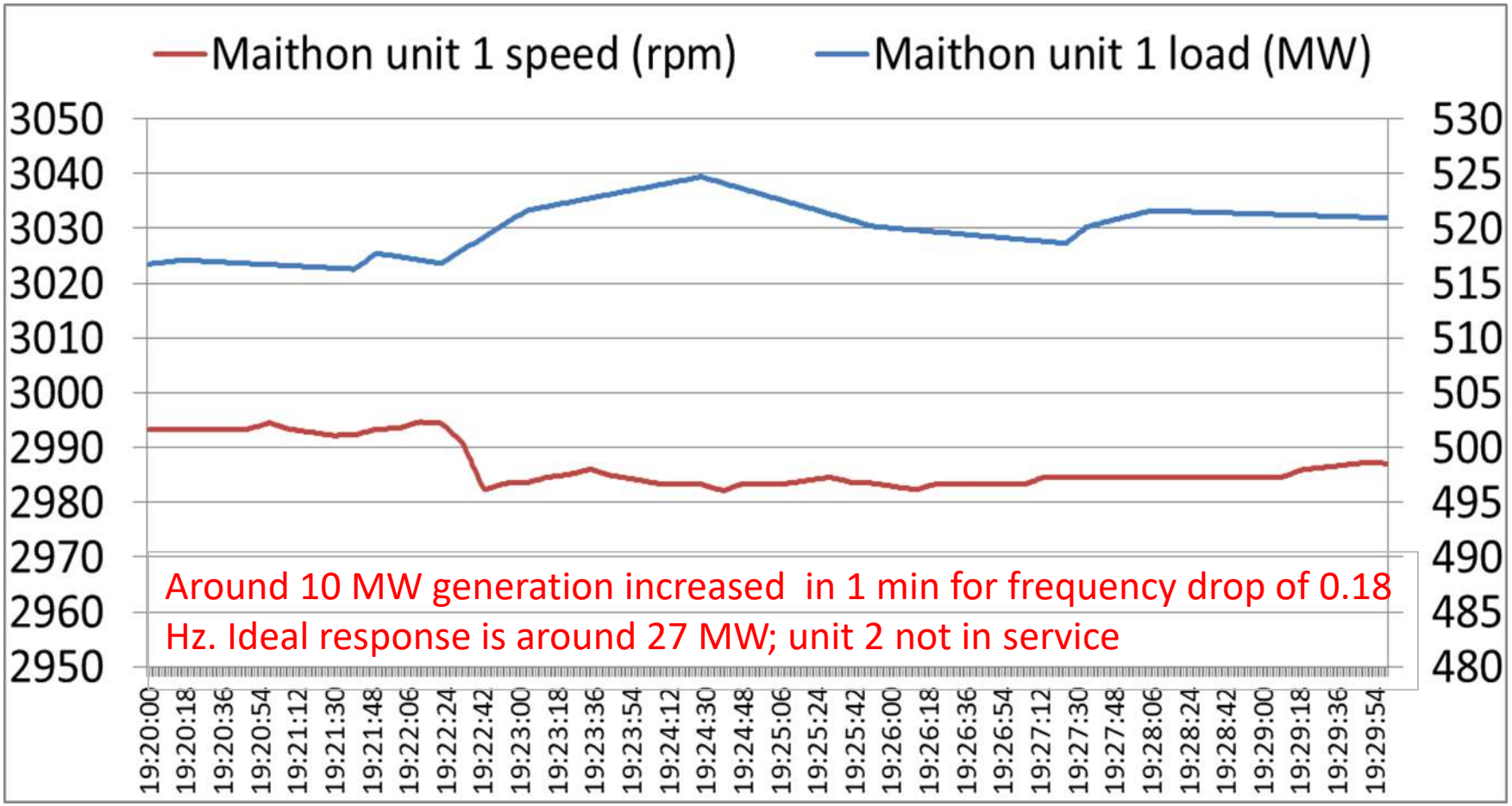
| Event No | Date | Time | Frequency Change | MPL generation Change after the Event (As per ERLDC SCADA in MW) | Actual response as % of Ideal Response (Assuming 5 % Droop) |
|---|---|---|---|---|---|
| Event-1 | 23-04-18 | 10:42 | 0.287 Hz Dip | 1.98 | 6 % |
| Event-2 | 06-05-18 | 16:50 | 0.055 Hz Dip | -0.99 | -5 % |
| Event-3 | 10-05-18 | 06:11 | 0.054 Hz Dip | Data not Updating | Data not Updating |
| Event-4 | 10-07-18 | 08:14 | 0.062 Hz Dip | -3 | -14 % |
| Event-5 | 30-07-18 | 20:48 | 0.071 Hz Dip | 57 | 248 % |
| Event-6 | 06-08-18 | 13:06 | 0.13 Hz Rise | -20 | 143 % |
| Event-7 | 07-08-18 | 14:17 | 0.035 Hz Dip | 10.9 | 102 % |
| Event-8 | 29-08-18 | 04:02 | 0.056 Hz Dip | -1.6 | -5 % |
| Event-9 | 30-10-18 | 19:23 | 0.19 Hz Dip | 9.4 | 38 % |
| Event-10 | 16-01-19 | 12:25 | 0.05 Hz Dip | 1.3 | -6.9% |

# MPL response on 10th July 2018 at 08:14 hrs




* Based on ERLDC SCADA data

# MPL response on 30th October 2018 at 19:23 hrs

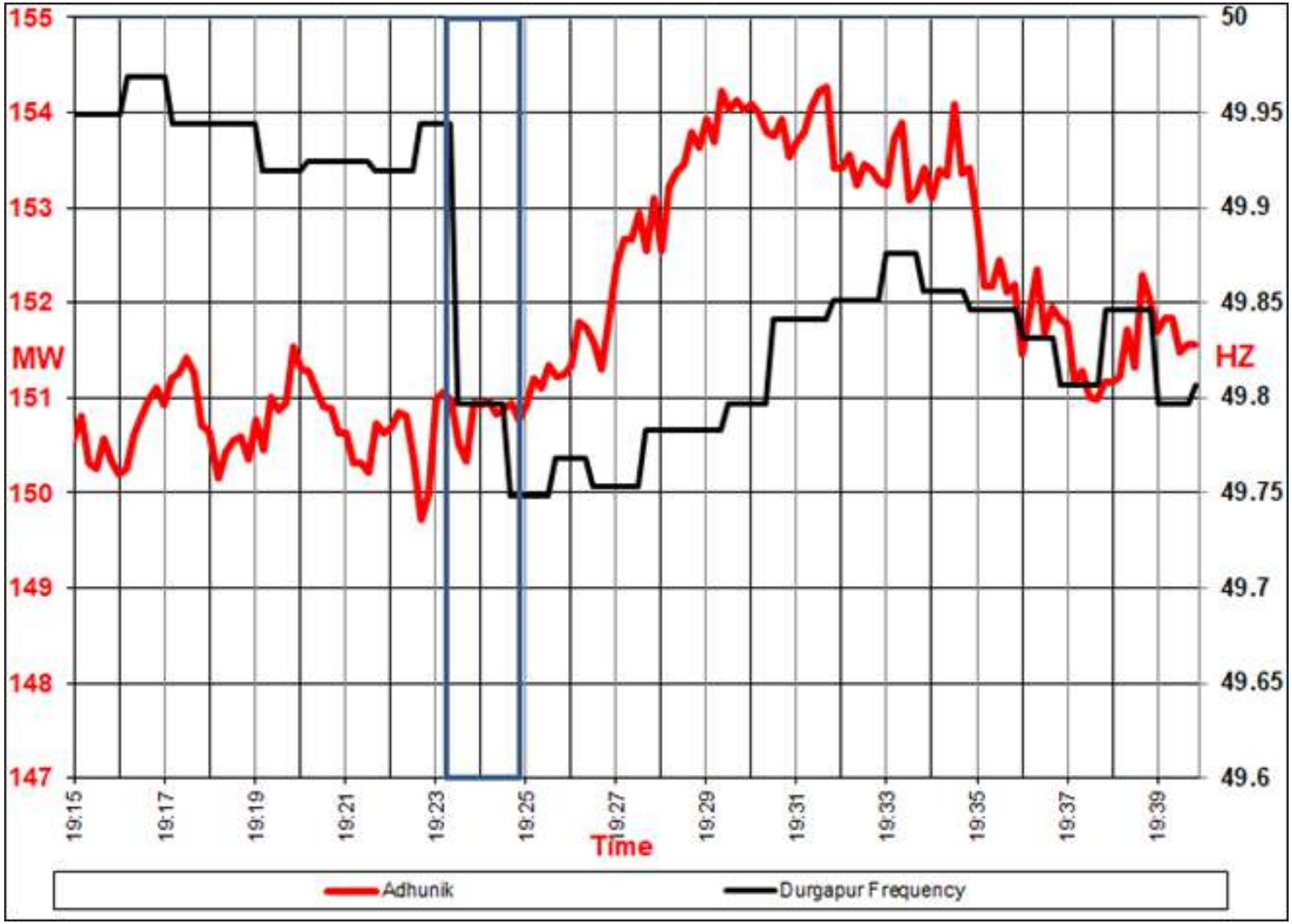



* Based on data received from MPL

# Adhunik

| Event No | Date | Time | Frequency Change | Adhunik MW Change after the Event (As per ERLDC SCADA) | Actual response as % of Ideal Response (Assuming 5 % Droop) |
|---|---|---|---|---|---|
| Event-1 | 23-04-18 | 10:42 | 0.287 Hz Dip | -1 | -15 % |
| Event-2 | 06-05-18 | 16:50 | 0.055 Hz Dip | 0.45 | 8 % |
| Event-3 | 10-05-18 | 06:11 | 0.054 Hz Dip | 4.66 | 87 % |
| Event-4 | 10-07-18 | 08:14 | 0.062 Hz Dip | 1.95 (Generation Ramp up in Unit going on) | 30 % |
| Event-5 | 30-07-18 | 20:48 | 0.071 Hz Dip | 1.76 (Generation Ramp up in Unit going on) | 21 % |
| Event-6 | 06-08-18 | 13:06 | 0.13 Hz Rise | -0.96 | 38 % |
| Event-7 | 07-08-18 | 14:17 | 0.035 Hz Dip | 0.69 (Generation Ramp up in Unit going on) | 40 % |
| Event-8 | 29-08-18 | 04:02 | 0.056 Hz Dip | 1.12 | 17 % |
| Event-9 | 30-10-18 | 19:23 | 0.19 Hz Dip | -0.29 | -4 % |
| Event-10 | 16-01-19 | 12:25 | 0.05 Hz Dip | Data not available | -- |

# Adhunik response on 30th October 2018 at 19:23 h

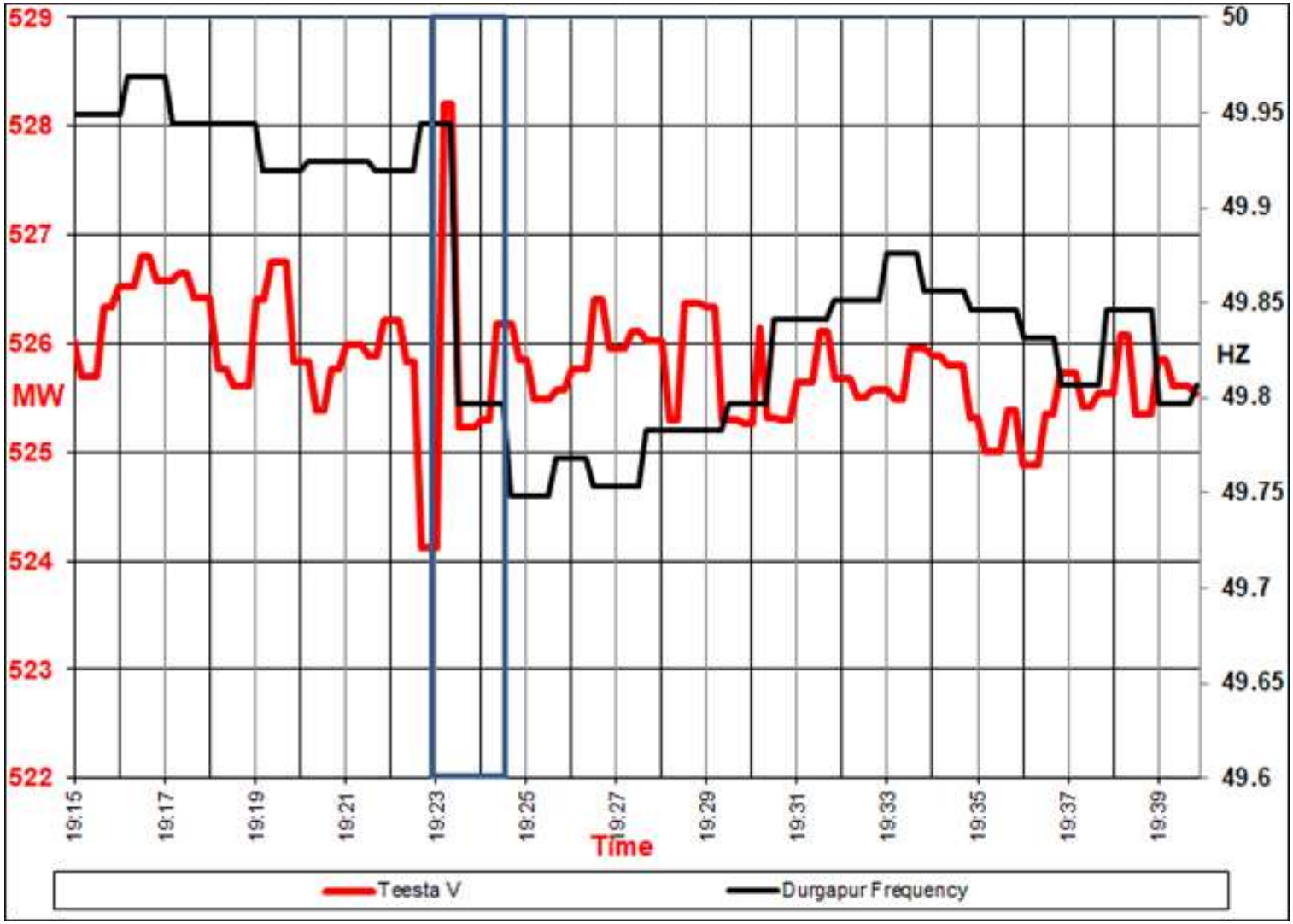



* Based on ERLDC SCADA data

# Teesta V

| Event No | Date | Time | Frequency Change | Teesta V MW Change after the Event (As per ERLDC SCADA) | Actual response as % of Ideal Response (Assuming 5 % Droop) |
|---|---|---|---|---|---|
| Event-1 | 23-04-18 | 10:42 | 0.287 Hz Dip | 0.22 | 3 % |
| Event-2 | 06-05-18 | 16:50 | 0.055 Hz Dip | No Units in Service | No Units in Service |
| Event-3 | 10-05-18 | 06:11 | 0.054 Hz Dip | 4.51 | 61 % |
| Event-4 | 10-07-18 | 08:14 | 0.062 Hz Dip | 0.12 | 1 % |
| Event-5 | 30-07-18 | 20:48 | 0.071 Hz Dip | 14.27 | 102 % |
| Event-6 | 06-08-18 | 13:06 | 0.13 Hz Rise | -2.7 | 28 % |
| Event-7 | 07-08-18 | 14:17 | 0.035 Hz Dip | -0.25 | -4 % |
| Event-8 | 29-08-18 | 04:02 | 0.056 Hz Dip | 1.61 | 7 % |
| Event-9 | 30-10-18 | 19:23 | 0.19 Hz Dip | -2.33 | -9 % |
| Event-10 | 16-01-19 | 12:25 | 0.05 Hz Dip | Unit not in service | -- |

# Teesta V response on 30th October 2018 at 19:23 h

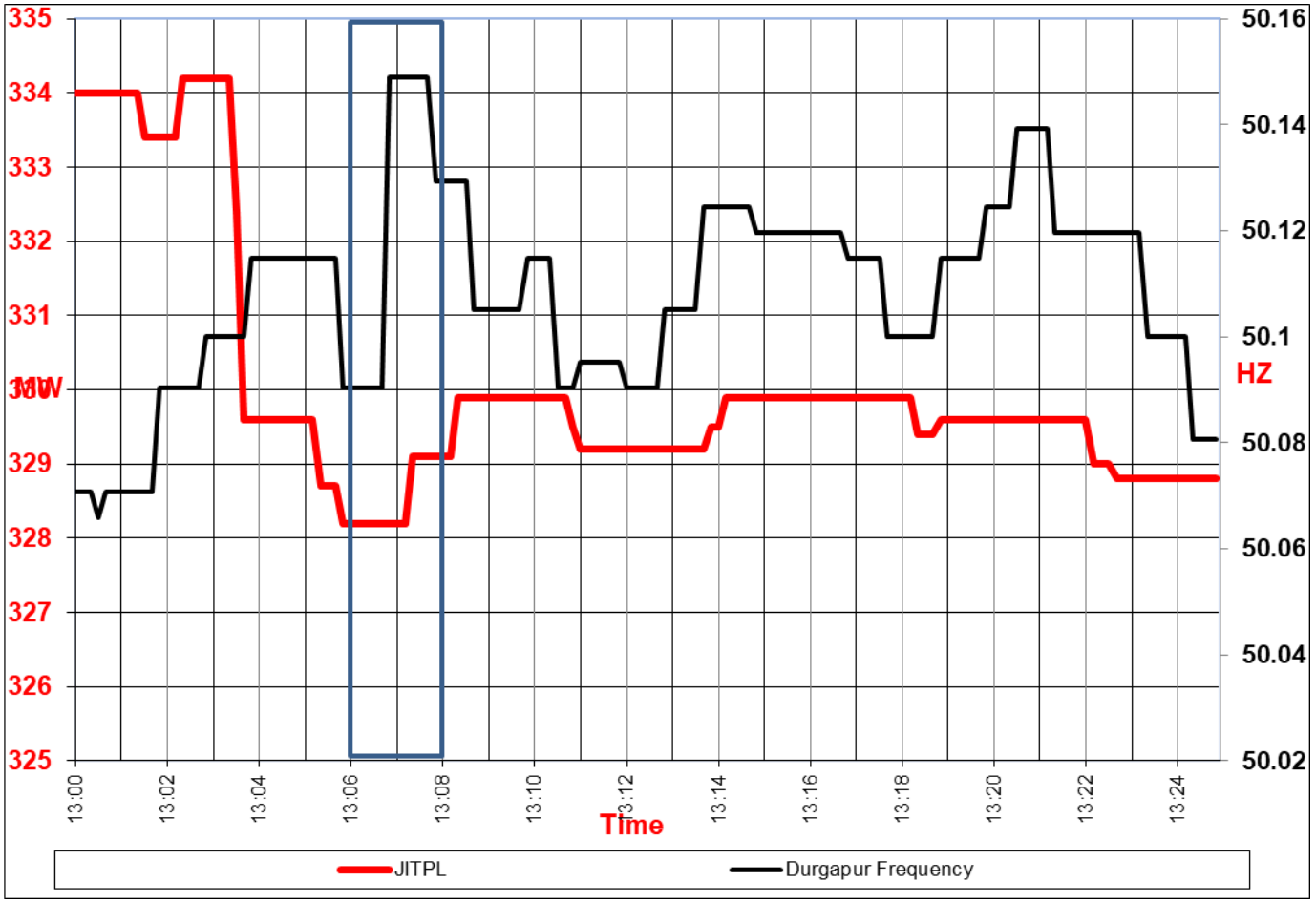



* Based on ERLDC SCADA data

# JITPL

| Event No | Date | Time | Frequency Change | JITPL MW Change after the Event (As per ERLDC SCADA) | Actual response as % of Ideal Response (Assuming 5 % Droop) |
|---|---|---|---|---|---|
| Event-1 | 23-04-18 | 10:42 | 0.287 Hz Dip | 0.7 | 1.3% |
| Event-2 | 06-05-18 | 16:50 | 0.055 Hz Dip | -0.7 | -4.8% |
| Event-3 | 10-05-18 | 06:11 | 0.054 Hz Dip | -1.5 | -16.3% |
| Event-4 | 10-07-18 | 08:14 | 0.062 Hz Dip | 0 | 0% |
| Event-5 | 30-07-18 | 20:48 | 0.071 Hz Dip | -0.1 | -0.9% |
| Event-6 | 06-08-18 | 13:06 | 0.13 Hz Rise | 0.9 | -13.7% |
| Event-7 | 07-08-18 | 14:17 | 0.035 Hz Dip | 0.8 | 14.9% |
| Event-8 | 29-08-18 | 04:02 | 0.056 Hz Dip | 3.8 | 49.7% |
| Event-9 | 30-10-18 | 19:23 | 0.19 Hz Dip | 1 | 2.8% |
| Event-10 | 16-01-19 | 12:25 | 0.05 Hz Dip | 3 | 32.5% |

# JITPL response on 06th August 2018 at 13:06 hrs

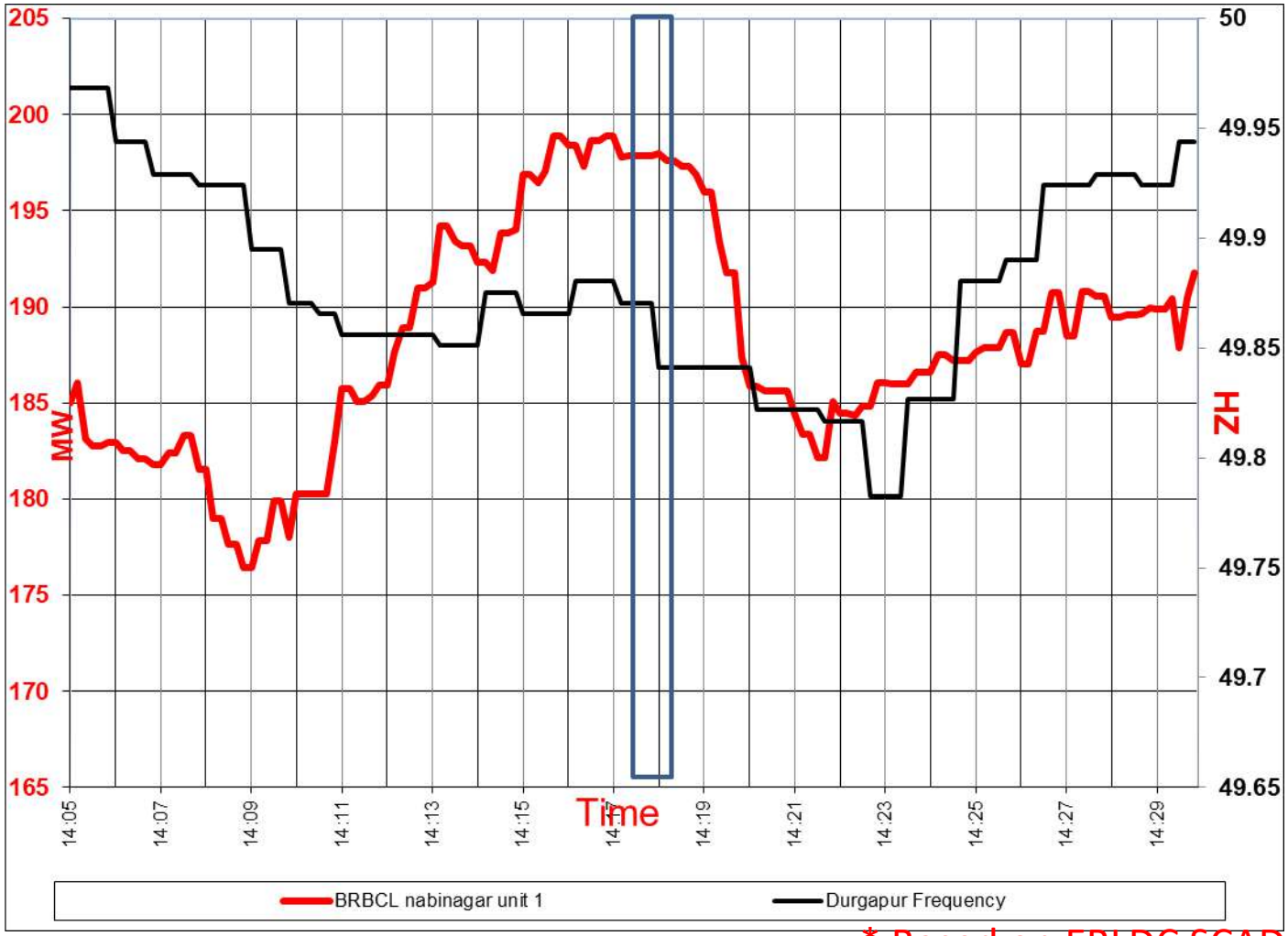



* Based on ERLDC SCADA data

# BRBCL

| Event No | Date | Time | Frequency Change | BRBCL MW Change after the Event (As per ERLDC SCADA) | Actual response as % of Ideal Response (Assuming 5 % Droop) |
|---|---|---|---|---|---|
| Event-1 | 23-04-18 | 10:42 | 0.287 Hz Dip | -0.2 | -1% |
| Event-2 | 06-05-18 | 16:50 | 0.055 Hz Dip | 2.1 | 55.5% |
| Event-3 | 10-05-18 | 06:11 | 0.054 Hz Dip | 1.7 | 36.8% |
| Event-4 | 10-07-18 | 08:14 | 0.062 Hz Dip | 3.6 | 74.9% |
| Event-5 | 30-07-18 | 20:48 | 0.071 Hz Dip | 0 | 0.0% |
| Event-6 | 06-08-18 | 13:06 | 0.13 Hz Rise | 1.7 | -47.6% |
| Event-7 | 07-08-18 | 14:17 | 0.035 Hz Dip | -0.95 | -34% |
| Event-8 | 29-08-18 | 04:02 | 0.056 Hz Dip | -2.4 | -70.2% |
| Event-9 | 30-10-18 | 19:23 | 0.19 Hz Dip | 5.4 | 17.6% |
| Event-10 | 16-01-19 | 12:25 | 0.05 Hz Dip | 0 | 0.0% |

# BRBCL response on 07th August 2018 at 14:17 hrs

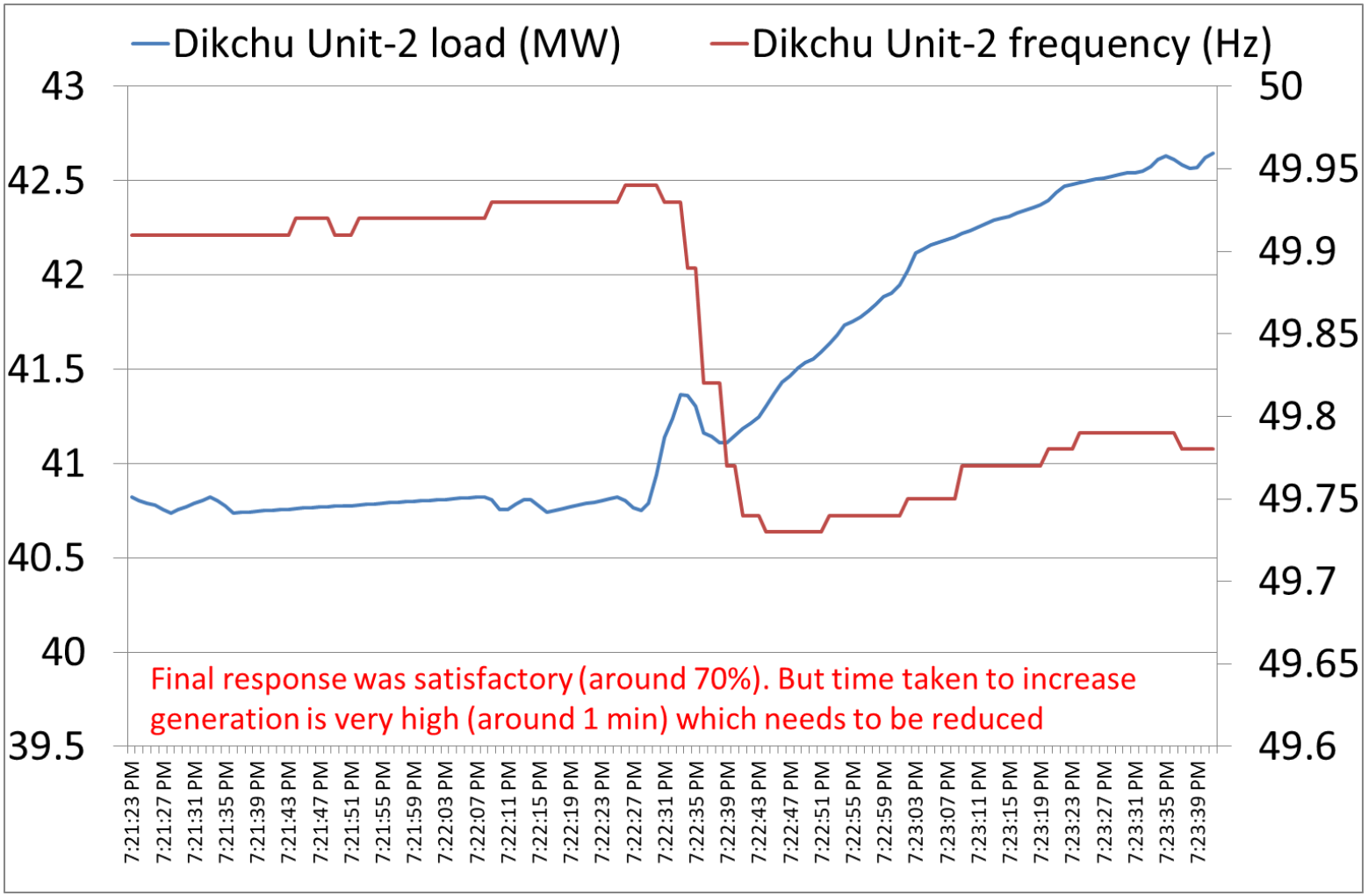



* Based on ERLDC SCADA data

# Dikchu

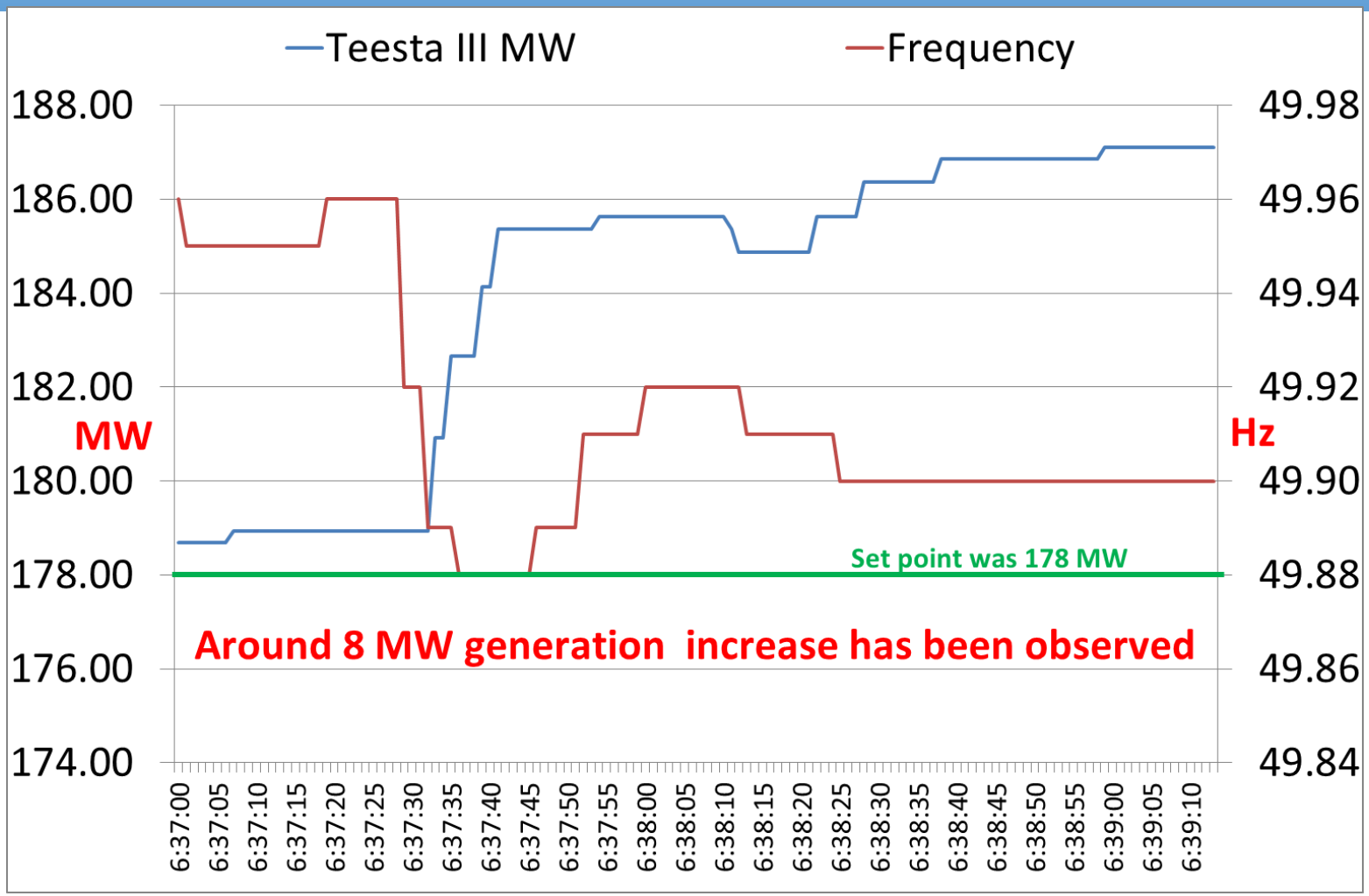
| Event No | Date | Time | Frequency Change | Dikchu MW Change after the Event (As per ERLDC SCADA) | Actual response as % of Ideal Response (Assuming 5 % Droop) |
|---|---|---|---|---|---|
| Event-1 | 23-04-18 | 10:42 | 0.287 Hz Dip | 0.3 | 5.38% |
| Event-2 | 06-05-18 | 16:50 | 0.055 Hz Dip | 0.1 | 5.3% |
| Event-3 | 10-05-18 | 06:11 | 0.054 Hz Dip | -0.3 | -12.7% |
| Event-4 | 10-07-18 | 08:14 | 0.062 Hz Dip | -- | -- |
| Event-5 | 30-07-18 | 20:48 | 0.071 Hz Dip | -- | -- |
| Event-6 | 06-08-18 | 13:06 | 0.13 Hz Rise | -0.5 | 26.3% |
| Event-7 | 07-08-18 | 14:17 | 0.035 Hz Dip | 0 | 0% |
| Event-8 | 29-08-18 | 04:02 | 0.056 Hz Dip | 0 | 0% |
| Event-9 | 30-10-18 | 19:23 | 0.19 Hz Dip | Data not available | |
| Event-10 | 16-01-19 | 12:25 | 0.05 Hz Dip | Unit not in service | -- |

# Dikchu response on 30th October 2018 at 19:23 hrs




* Based on data received from Dikchu

# Teesta III response on 23rd January 2019 at 06:37 h




Units at Teesta III was not in RGMO/FGMO before 06-12-2018. During Event on 16-01-18 , units at Teesta III were not in service.

* Based on data received from Teesta III

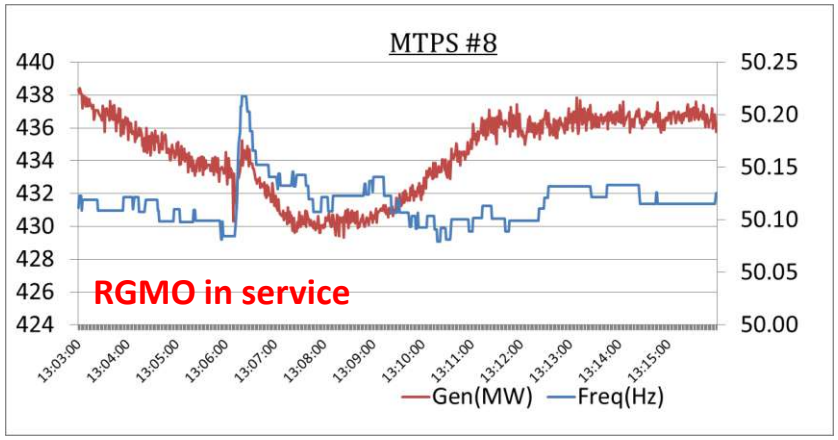
# Jharkhand

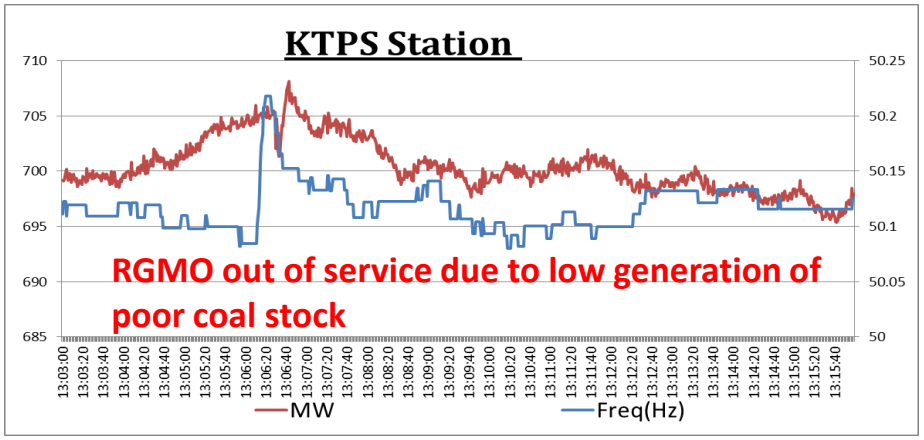
| Event No | Date | Time | Frequency Change | Jharkhand MW drawl Change after the Event (As per ERLDC SCADA) | Actual response as % of Ideal Response (Assuming 5 % Droop) |
|---|---|---|---|---|---|
| Event-1 | 23-04-18 | 10:42 | 0.287 Hz Dip | -8.9 | 28.6% |
| Event-2 | 06-05-18 | 16:50 | 0.055 Hz Dip | -7.3 | 131.3% |
| Event-3 | 10-05-18 | 06:11 | 0.054 Hz Dip | 24.7 | -439% |
| Event-4 | 10-07-18 | 08:14 | 0.062 Hz Dip | 24 | 439% |
| Event-5 | 30-07-18 | 20:48 | 0.071 Hz Dip | -24.8 | 385.9% |
| Event-6 | 06-08-18 | 13:06 | 0.13 Hz Rise | -28.9 | -1909% |
| Event-7 | 07-08-18 | 14:17 | 0.035 Hz Dip | 5.4 | -167.4% |
| Event-8 | 29-08-18 | 04:02 | 0.056 Hz Dip | -9.2 | 145.3% |
| Event-9 | 30-10-18 | 19:23 | 0.19 Hz Dip | 11.7 | -116% |
| Event-10 | 16-01-19 | 12:25 | 0.05 Hz Dip | -13.5 | 227.2% |

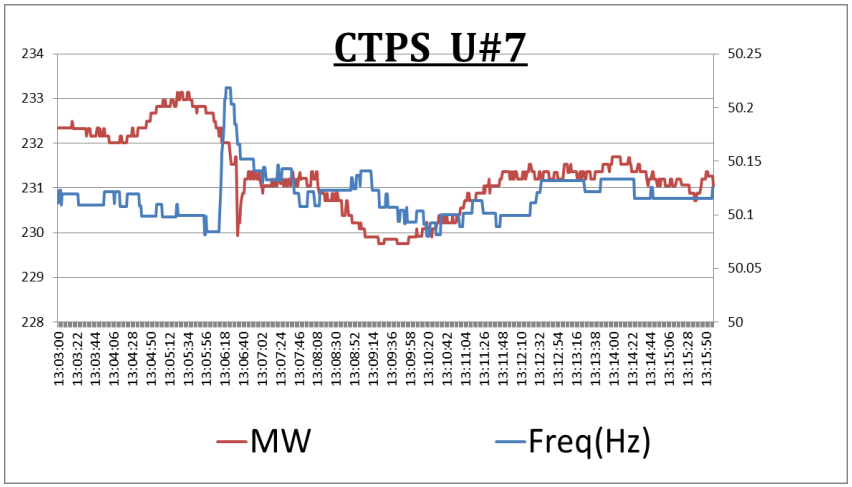
# DVC

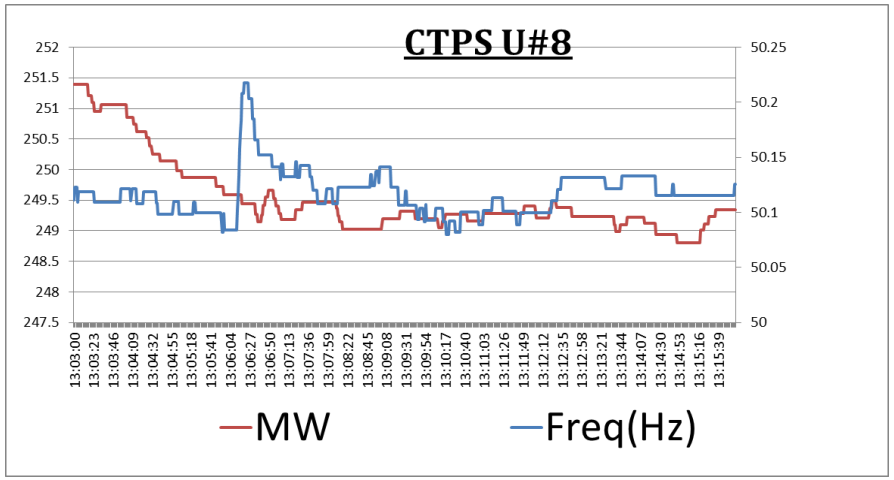
| Event No | Date | Time | Frequency Change | DVC MW drawl Change after the Event (As per ERLDC SCADA) | Actual response as % of Ideal Response (Assuming 5 % Droop) |
|---|---|---|---|---|---|
| Event-1 | 23-04-18 | 10:42 | 0.287 Hz Dip | -76.2 | 11.9% |
| Event-2 | 06-05-18 | 16:50 | 0.055 Hz Dip | 31.1 | -28.8% |
| Event-3 | 10-05-18 | 06:11 | 0.054 Hz Dip | -- | -- |
| Event-4 | 10-07-18 | 08:14 | 0.062 Hz Dip | -4.9 | 4.5% |
| Event-5 | 30-07-18 | 20:48 | 0.071 Hz Dip | -34.1 | 23.9% |
| Event-6 | 06-08-18 | 13:06 | 0.13 Hz Rise | 58.8 | 78.4% |
| Event-7 | 07-08-18 | 14:17 | 0.035 Hz Dip | -44.9 | 88.9% |
| Event-8 | 29-08-18 | 04:02 | 0.056 Hz Dip | -60.3 | 73.6% |
| Event-9 | 30-10-18 | 19:23 | 0.19 Hz Dip | -17 | 5% |
| Event-10 | 16-01-19 | 12:25 | 0.05 Hz Dip | -92.5 | 101.1% |

# Response observed at DVC units for 06th August event



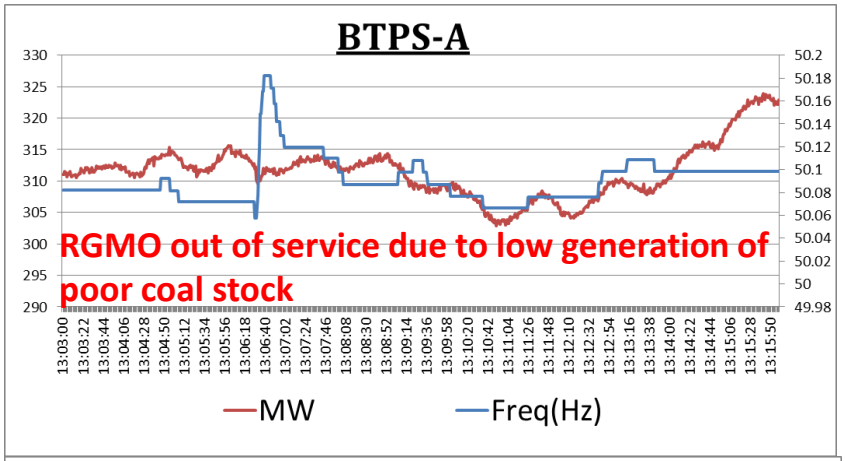



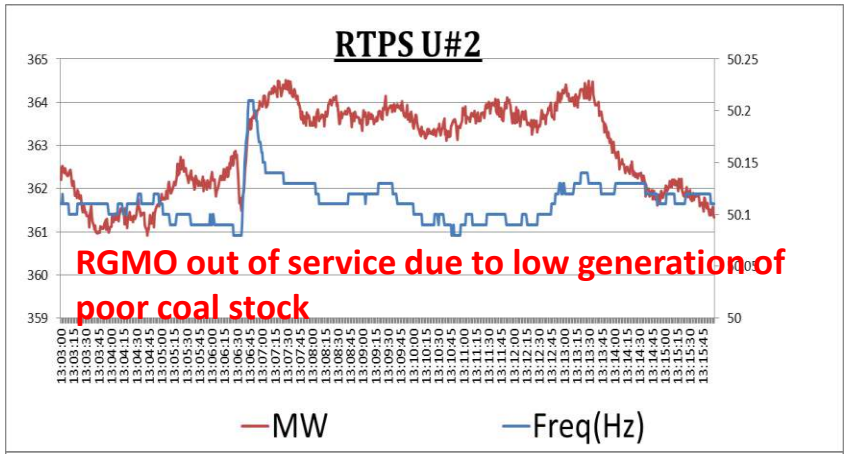



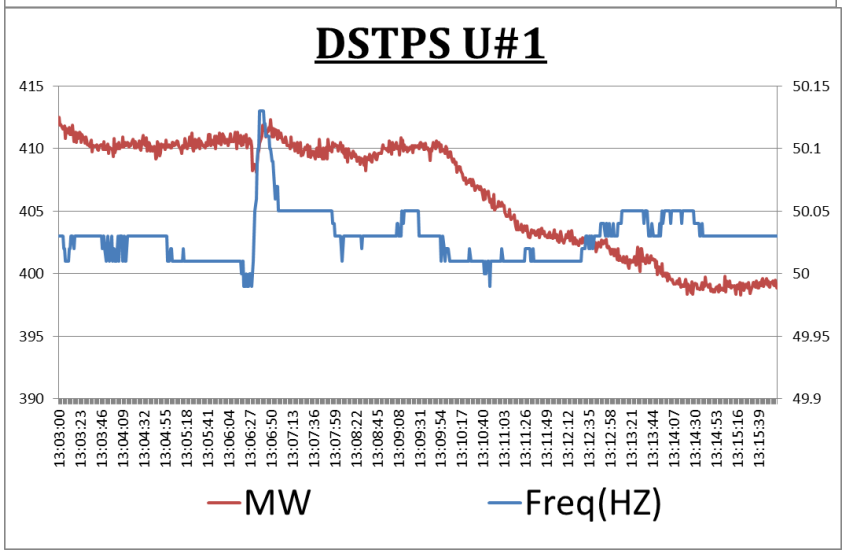

Response observed only for CTPS units

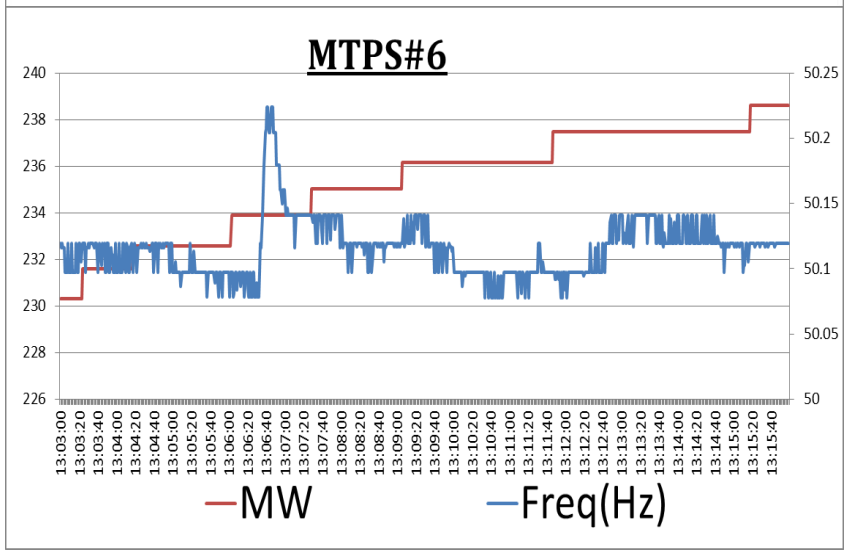
Frequency response observed in DVC control area for this event was 78% of ideal response (Assuming 5% governor droop and 4%/Hz load response)

# Response observed at DVC units for 06th August event



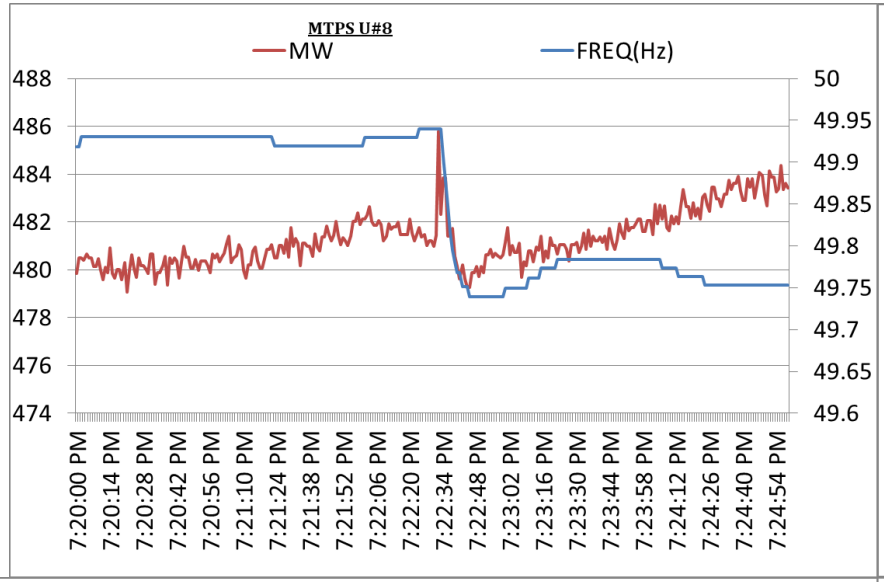



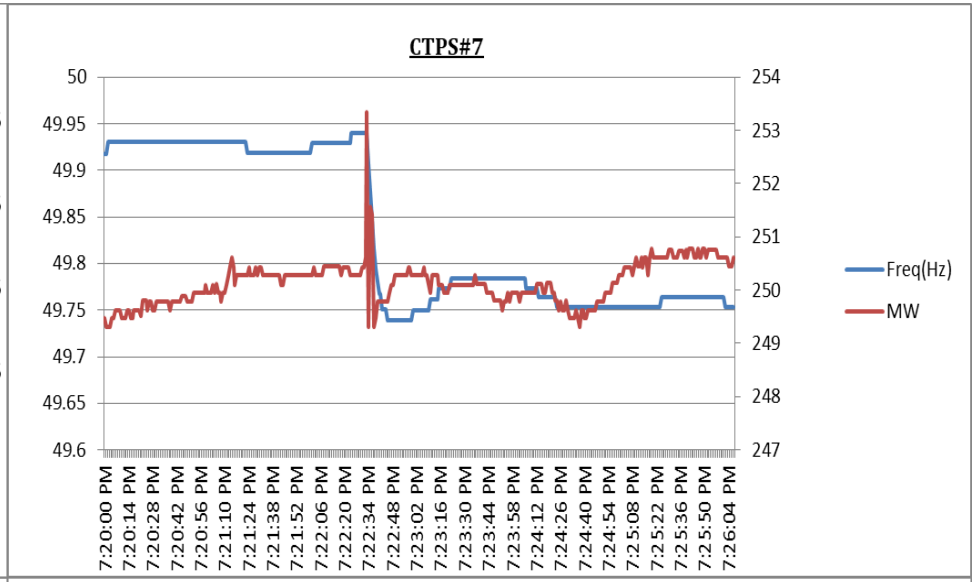

Response not observed for any unit

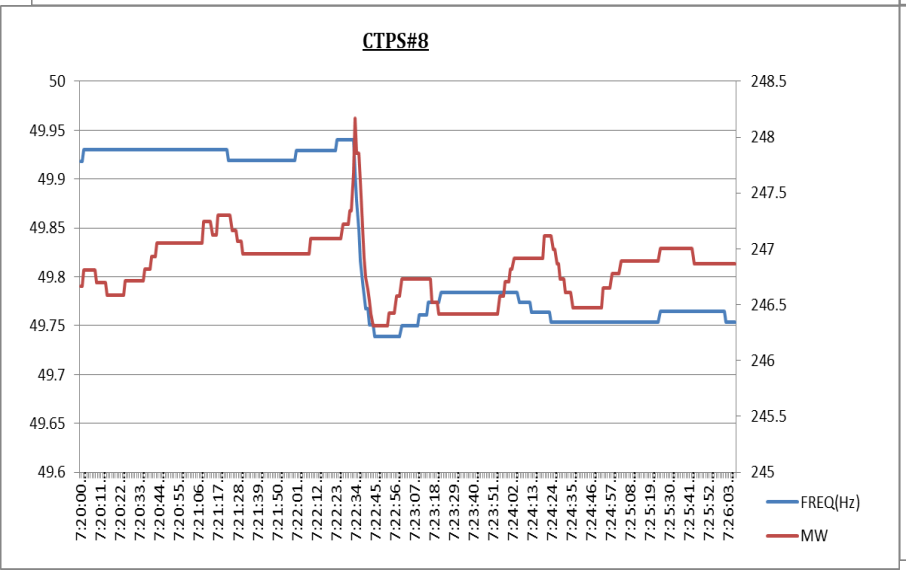
Frequency response observed in DVC control area for this event was 78% of ideal response (Assuming 5% governor droop and 4%/Hz load response)

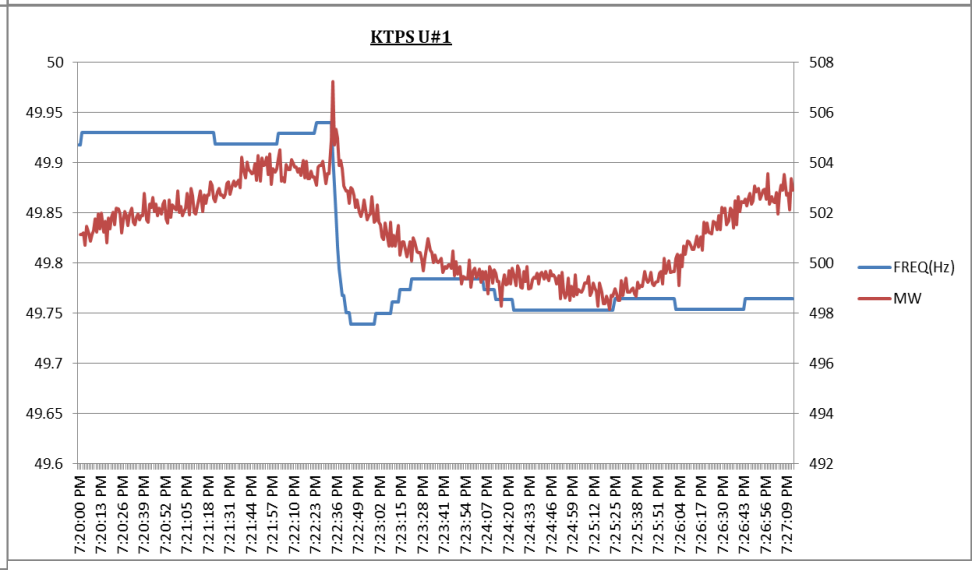
Load was in decreasing mode prior to the incident.

# Response observed at DVC units for 30th October event



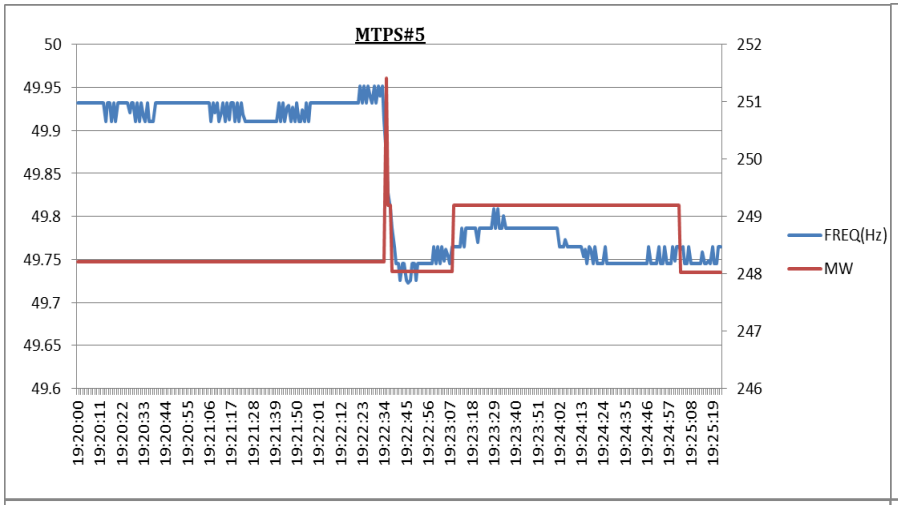



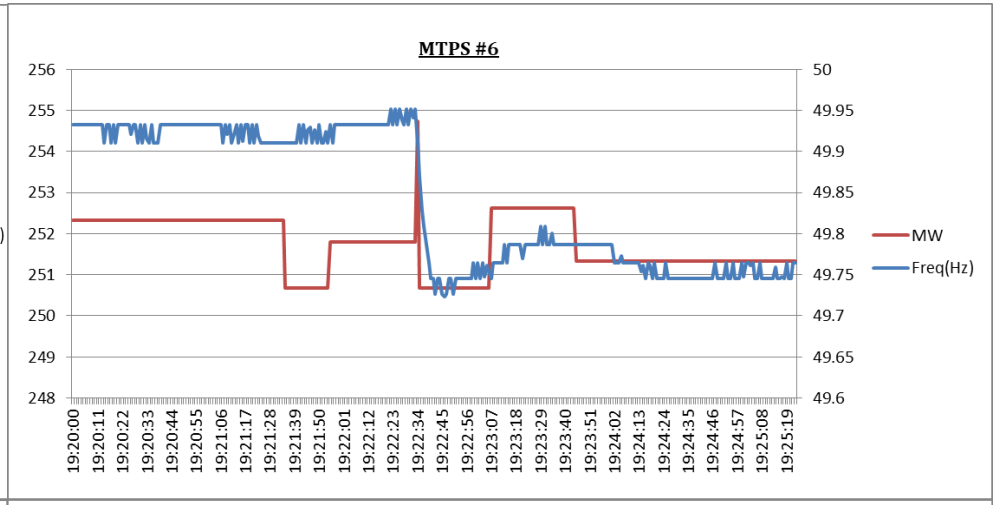



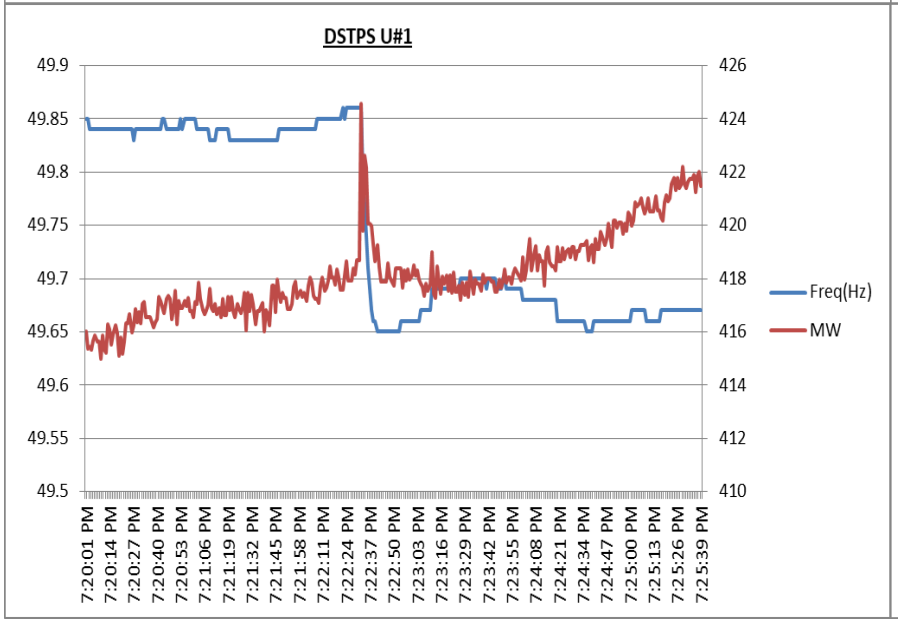



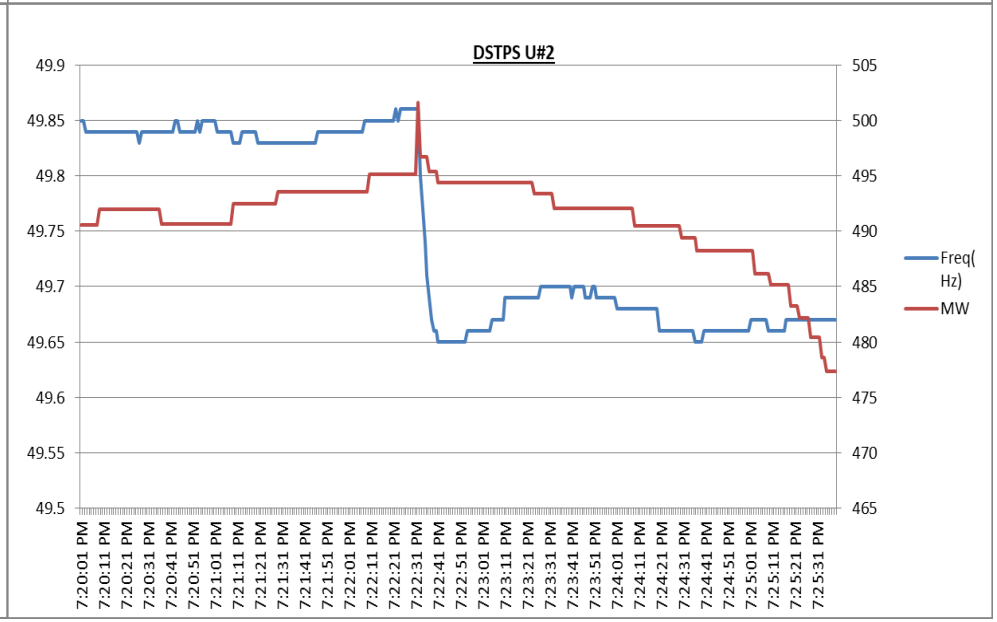

* Based on data received from DVC

# Response observed at DVC units for 30th October event



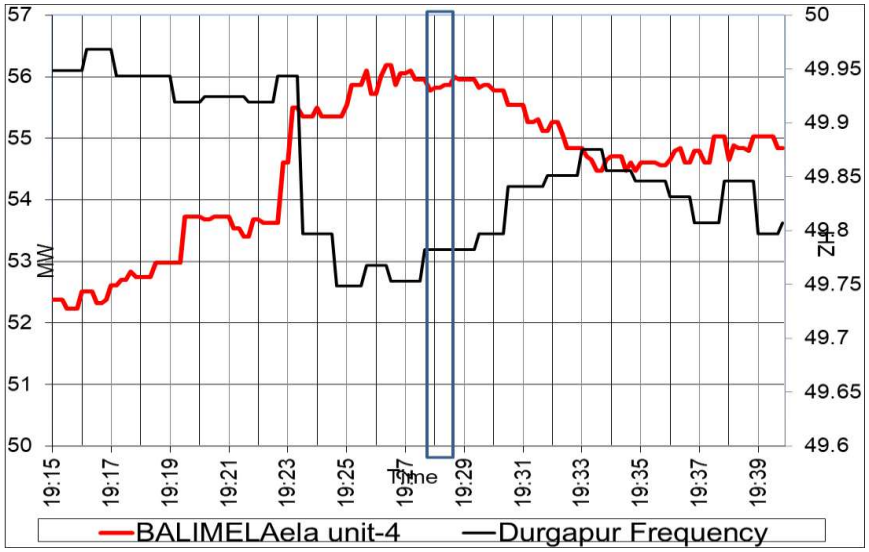



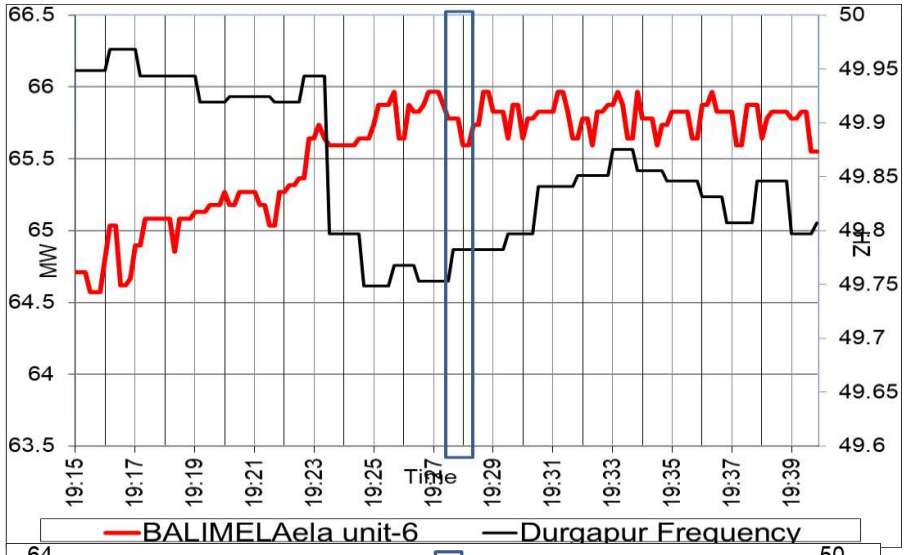

* Based on data received from DVC

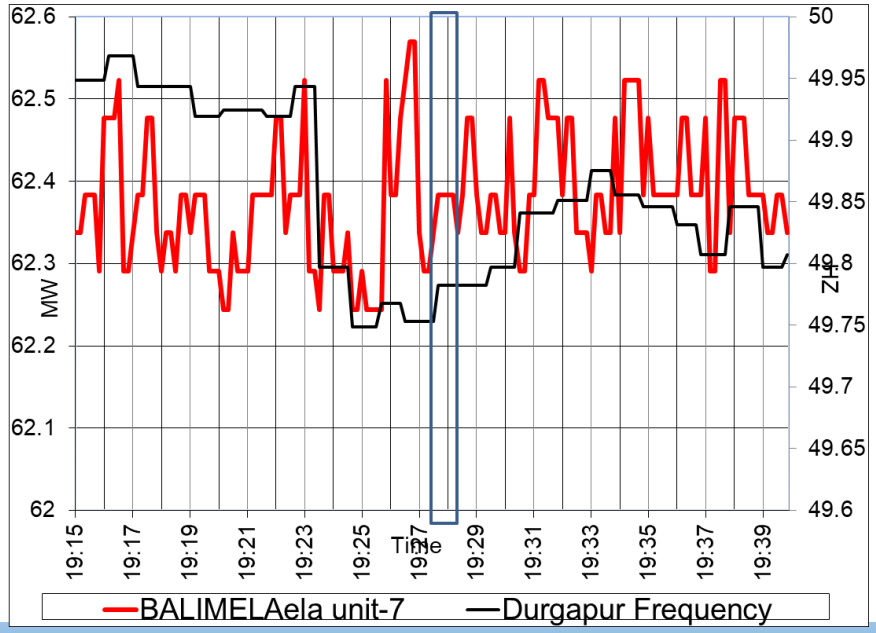
# GRIDCO

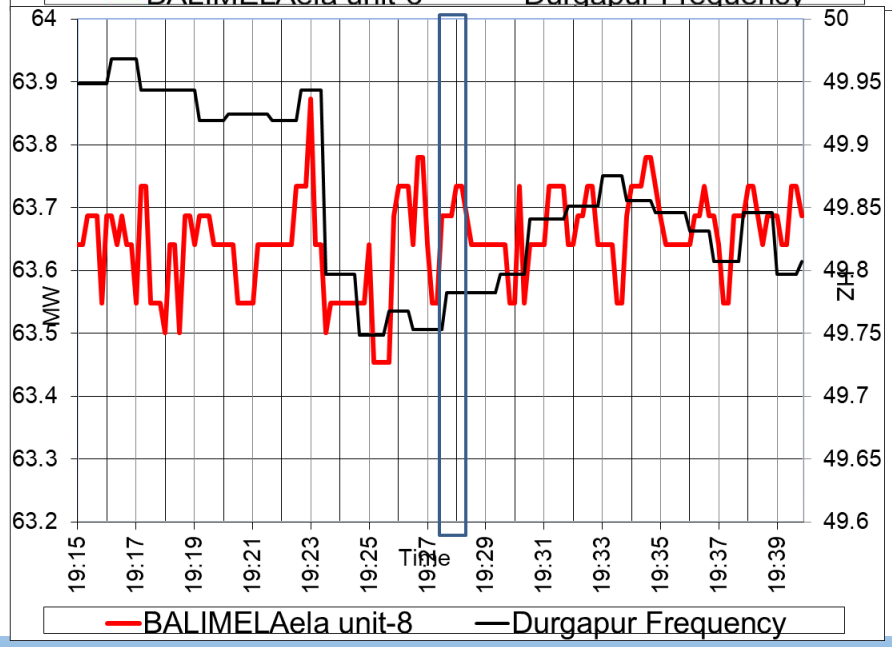
| Event No- | Date | Time | Frequency Change | GRIDCO MW drawl Change after the Event (As per ERLDC SCADA) | Actual response as % of Ideal Response (Assuming 5 % Droop) |
|---|---|---|---|---|---|
| Event-1 | 23-04-18 | 10:42 | 0.287 Hz Dip | -78.2 | 28.2% |
| Event-2 | 06-05-18 | 16:50 | 0.055 Hz Dip | -106.4 | 221.0% |
| Event-3 | 10-05-18 | 06:11 | 0.054 Hz Dip | -29.7 | 61.1% |
| Event-4 | 10-07-18 | 08:14 | 0.062 Hz Dip | -17.6 | 34.5% |
| Event-5 | 30-07-18 | 20:48 | 0.071 Hz Dip | 123.5 | -178.5% |
| Event-6 | 06-08-18 | 13:06 | 0.13 Hz Rise | 17.2 | 38.2% |
| Event-7 | 07-08-18 | 14:17 | 0.035 Hz Dip | 39.9 | -146.2% |
| Event-8 | 29-08-18 | 04:02 | 0.056 Hz Dip | -39.4 | 64.7% |
| Event-9 | 30-10-18 | 19:23 | 0.19 Hz Dip | 74 | -29.9% |
| Event-10 | 16-01-19 | 12:25 | 0.05 Hz Dip | 25.1 | 52.4% |

# Response observed at GRICO units for 30th October event



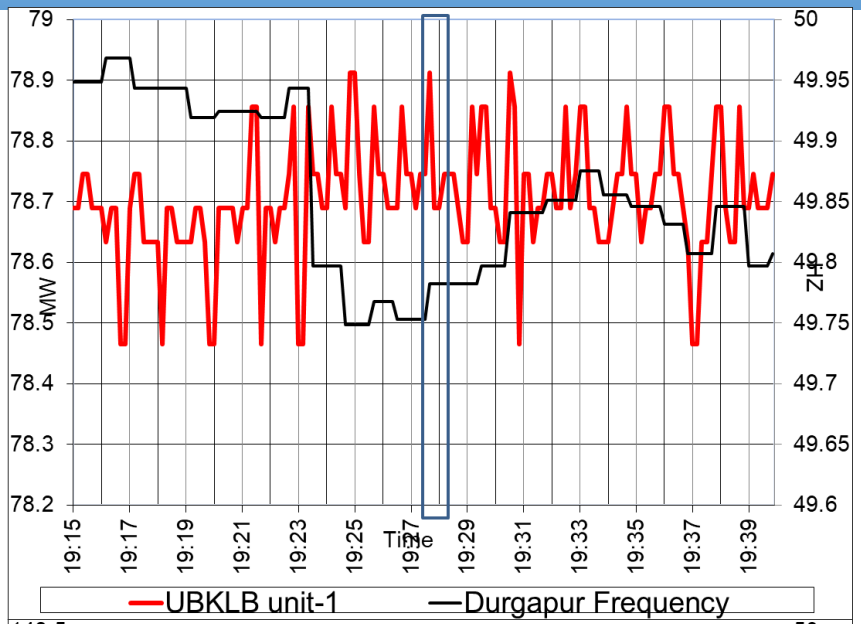



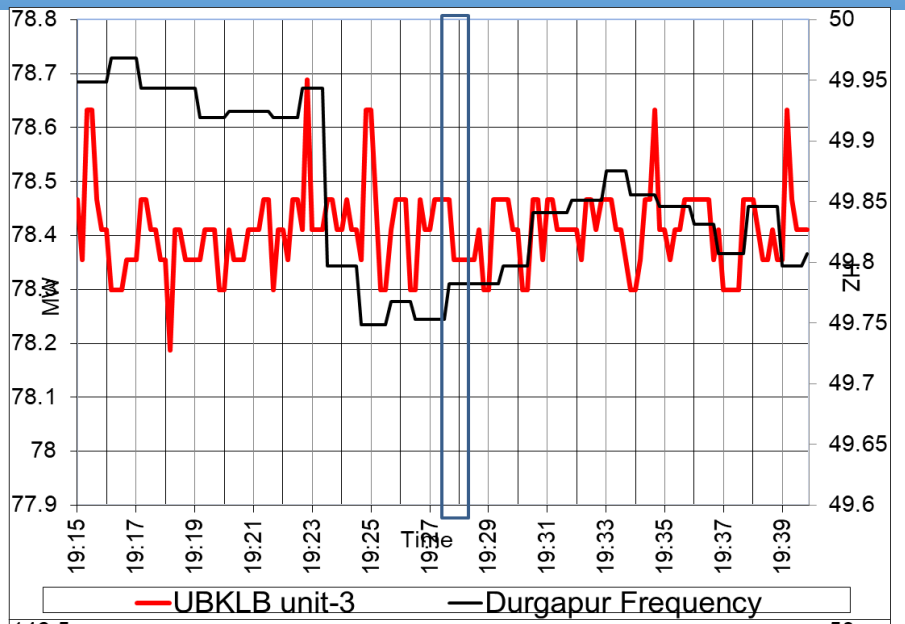



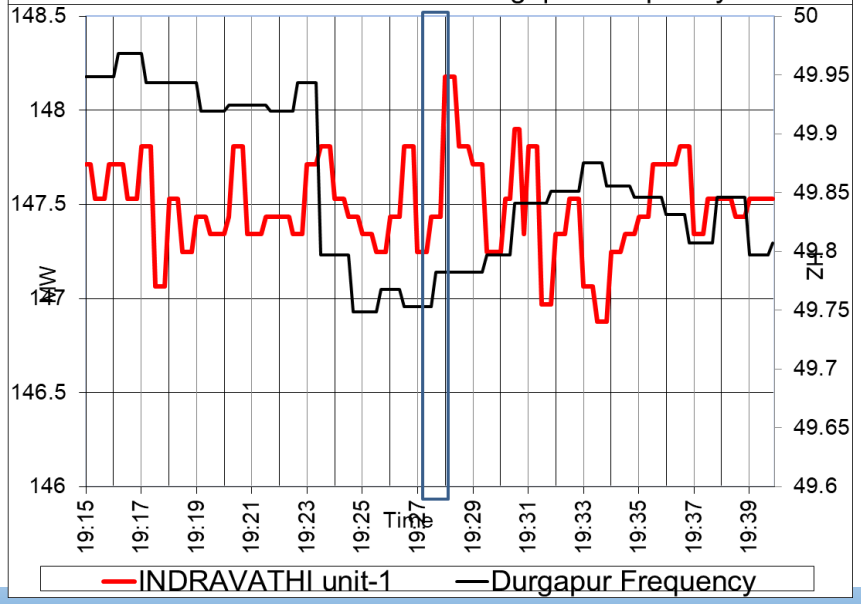



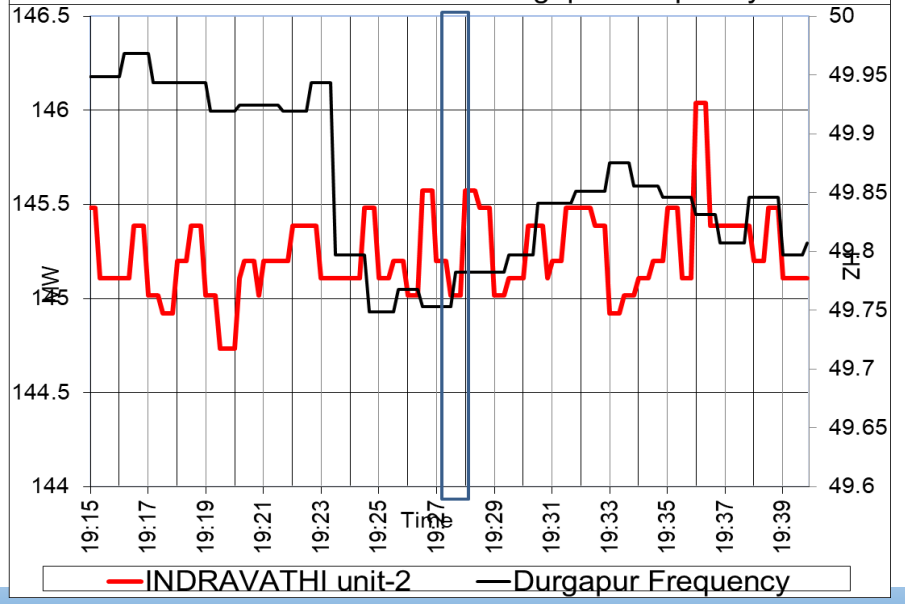

* Based on data received from ERLDC SCADA data

# Response observed at GRICO units for 30th October event



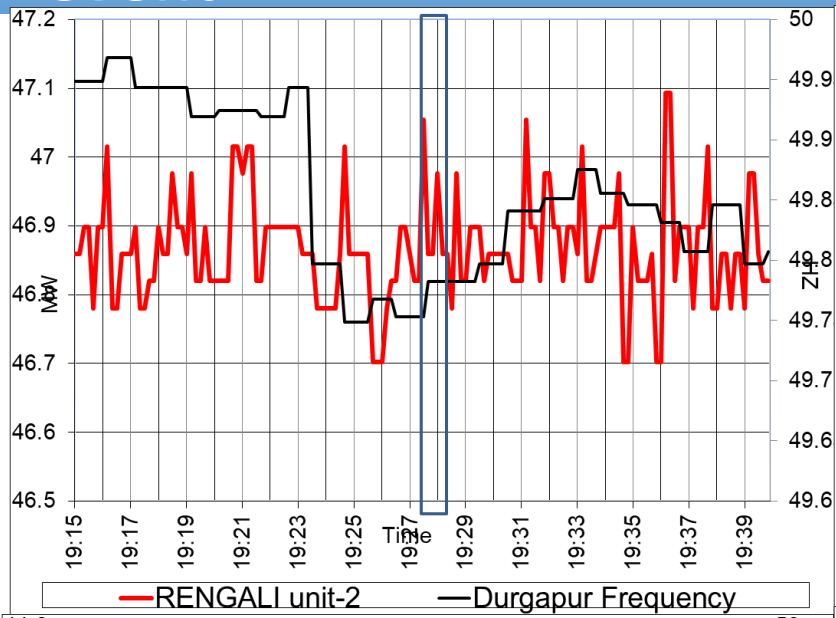



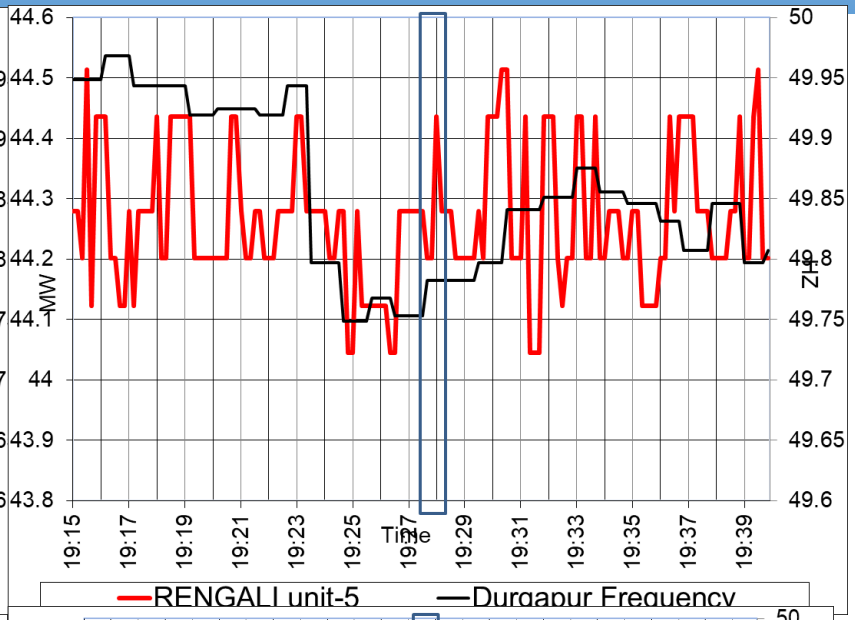



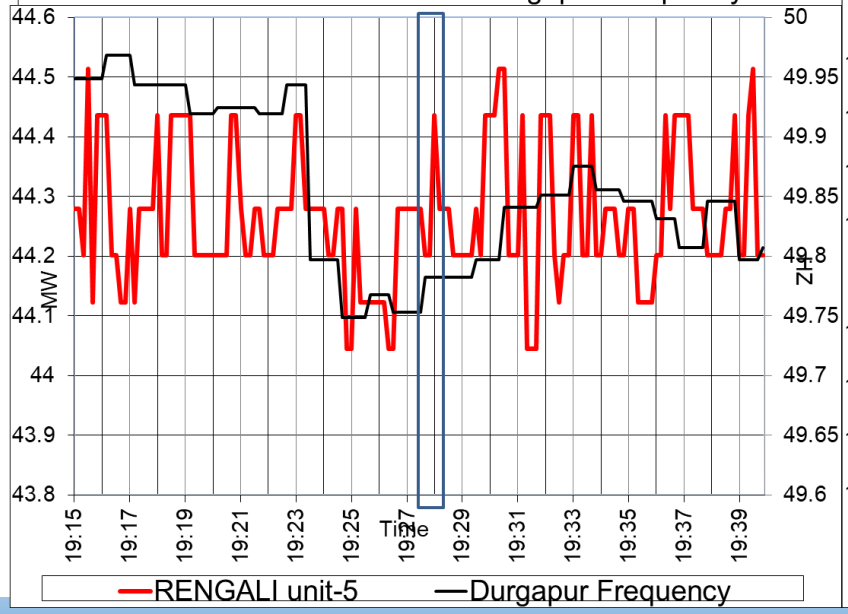



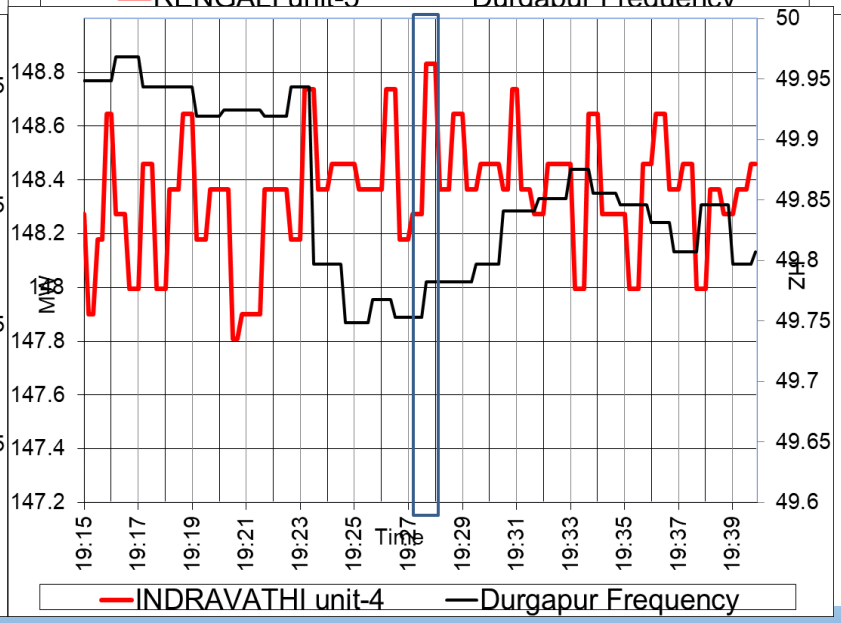

* Based on data received from ERLDC SCADA data

# Response observed at GRICO units for 30th October event



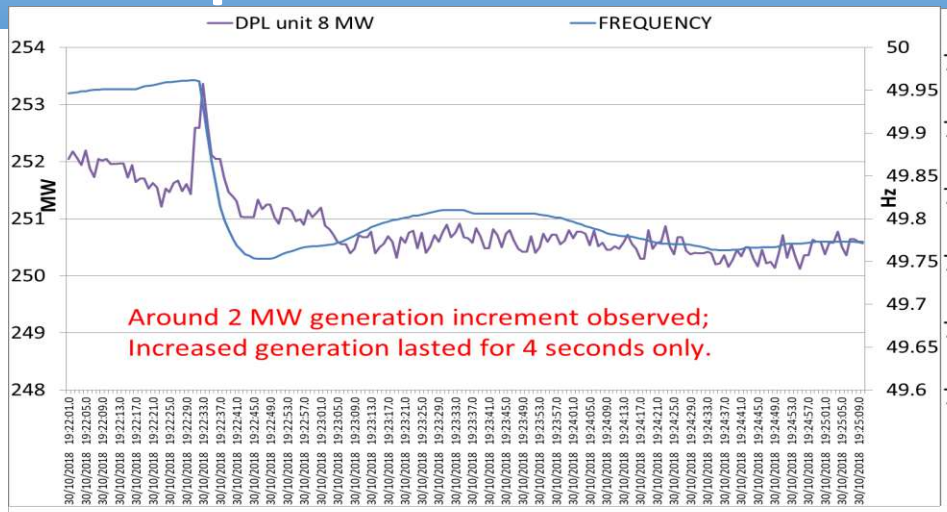



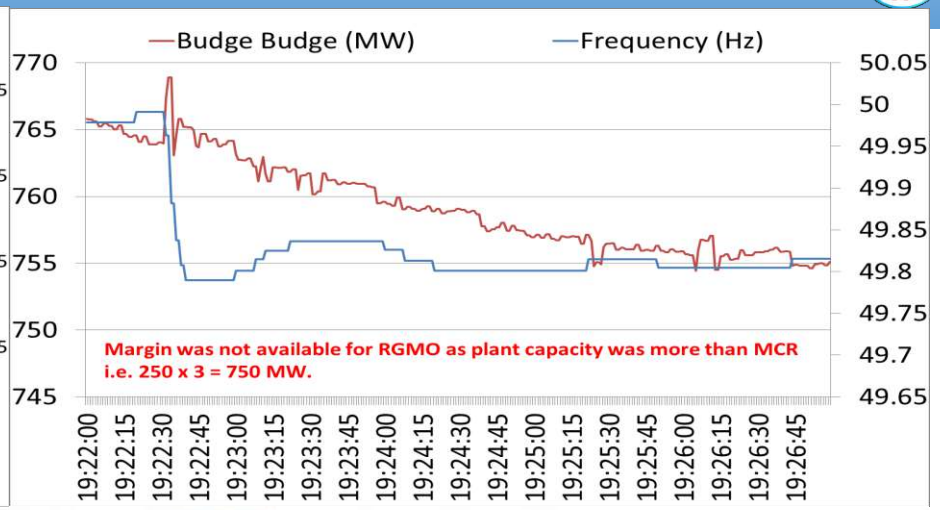

* Based on data received from ERLDC SCADA data

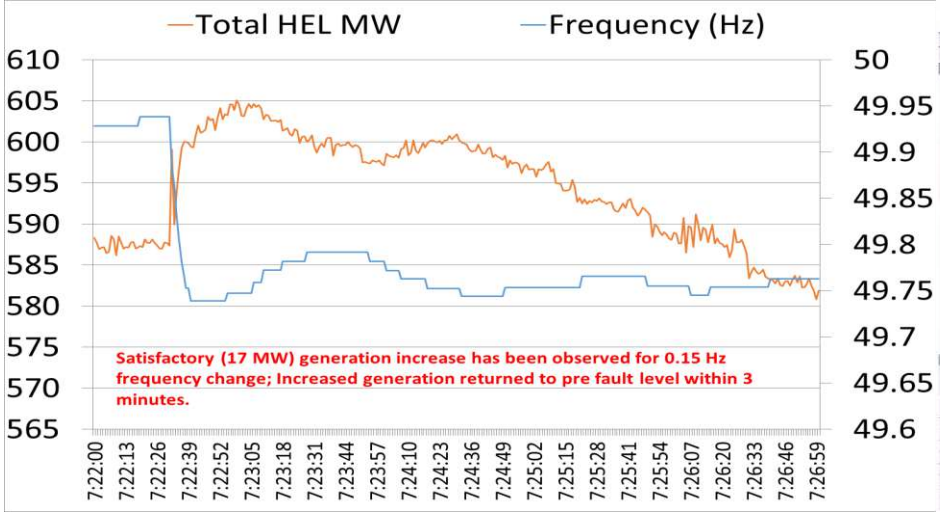
# WB

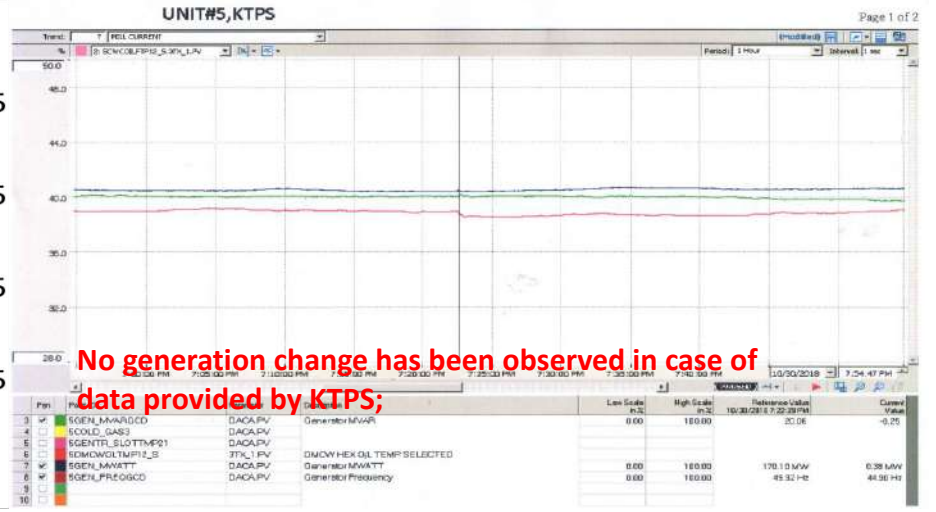
| Event No | Date | Time | Frequency Change | WB MW drawl Change after the Event (As per ERLDC SCADA) | Actual response as % of Ideal Response (Assuming 5 % Droop) |
|---|---|---|---|---|---|
| Event-1 | 23-04-18 | 10:42 | 0.287 Hz Dip | -46.8 | 7.6% |
| Event-2 | 06-05-18 | 16:50 | 0.055 Hz Dip | -43.4 | 37.3% |
| Event-3 | 10-05-18 | 06:11 | 0.054 Hz Dip | 13.3 | -12.3% |
| Event-4 | 10-07-18 | 08:14 | 0.062 Hz Dip | -51.7 | 41.3% |
| Event-5 | 30-07-18 | 20:48 | 0.071 Hz Dip | -44.3 | 24.9% |
| Event-6 | 06-08-18 | 13:06 | 0.13 Hz Rise | -13.7 | -14.9% |
| Event-7 | 07-08-18 | 14:17 | 0.035 Hz Dip | 12 | -19% |
| Event-8 | 29-08-18 | 04:02 | 0.056 Hz Dip | 14.2 | -12.3% |
| Event-9 | 30-10-18 | 19:23 | 0.19 Hz Dip | -45.1 | 10.9% |
| Event-10 | 16-01-19 | 12:25 | 0.05 Hz Dip | 18.2 | -20.6% |

# Response observed at WB units for 30th October event



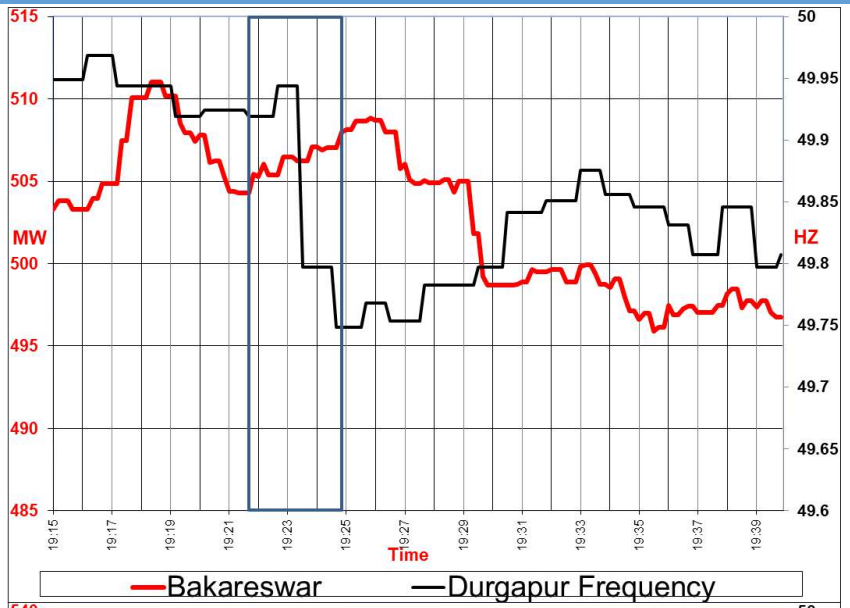



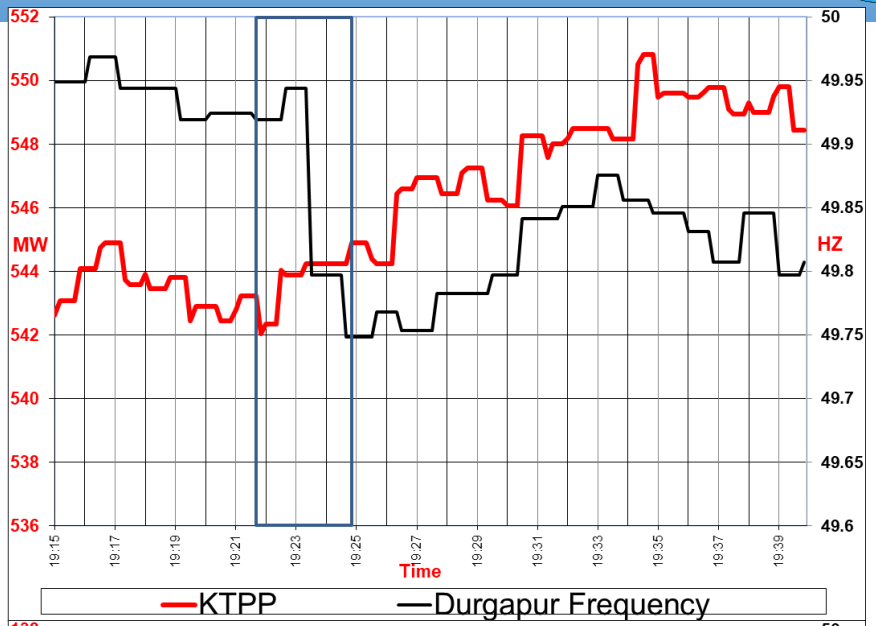



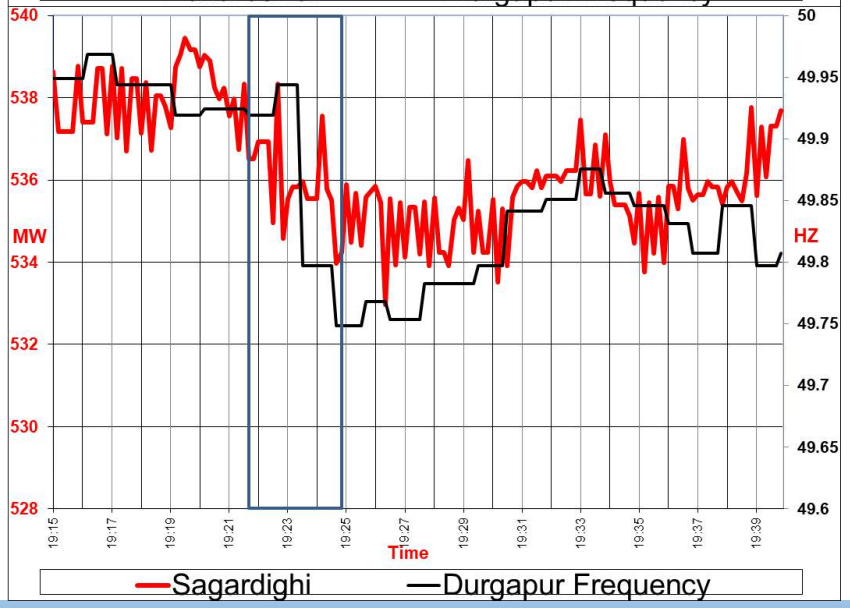

Frequency response observed in WB control area for this event was 11% of ideal response
(Assuming 5% governor droop and 4%/Hz load response)

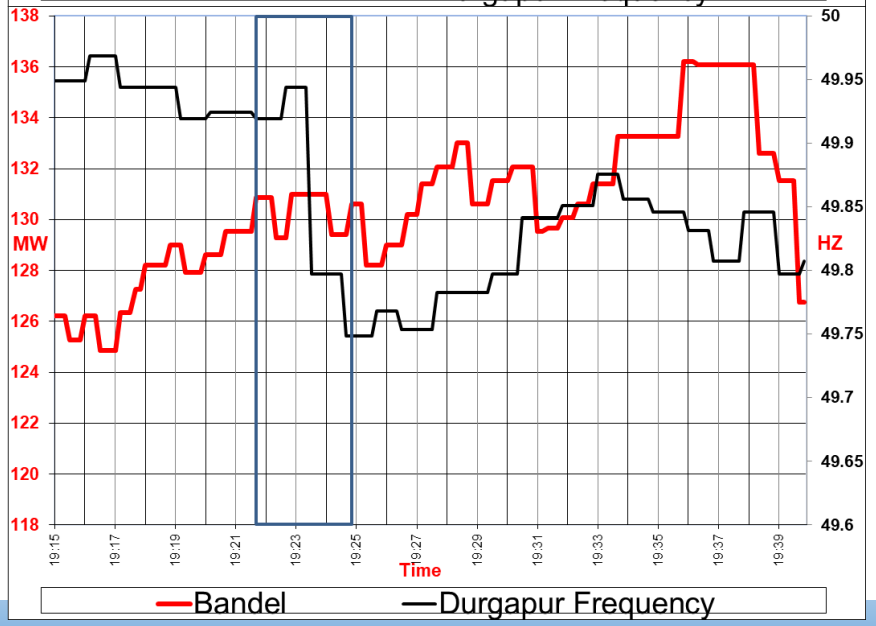
* Based on data received from generation end

# Response observed at WB units for 30th October event




* Based on data received from ERLDC SCADA data

# Sikkim

| Event No | Date | Time | Frequency Change | Sikkim MW Change after the Event (As per ERLDC SCADA) | Actual response as % of Ideal Response (Assuming 5 % Droop) |
|---|---|---|---|---|---|
| Event-1 | 23-04-18 | 10:42 | 0.287 Hz Dip | 0.1 | -3.6% |
| Event-2 | 06-05-18 | 16:50 | 0.055 Hz Dip | -0.1 | 42.3% |
| Event-3 | 10-05-18 | 06:11 | 0.054 Hz Dip | 1 | -266% |
| Event-4 | 10-07-18 | 08:14 | 0.062 Hz Dip | -0.5 | 124.5% |
| Event-5 | 30-07-18 | 20:48 | 0.071 Hz Dip | -0.8 | 165.4% |
| Event-6 | 06-08-18 | 13:06 | 0.13 Hz Rise | 0.4 | 120.9% |
| Event-7 | 07-08-18 | 14:17 | 0.035 Hz Dip | -0.3 | 157.5% |
| Event-8 | 29-08-18 | 04:02 | 0.056 Hz Dip | -0.4 | 140.8% |
| Event-9 | 30-10-18 | 19:23 | 0.19 Hz Dip | -0.7 | 50.7% |
| Event-10 | 16-01-19 | 12:25 | 0.05 Hz Dip | -0.1 | 36.7% |

# Thank you

**For any query,**

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9903329591

**RGMO/FGMO status:**

**A. ISGS and IPPs**

| Generator Name | Discussion during the meeting | Comments from Generators | Time frame and Action Plan |
|---|---|---|---|
| Farakka Unit 1,2,3 | Adequate Response is not observed due to old DCS system. | The DCS are old and due to any faulty card, response is not observed. The response will be intermittent as there is no facility to provide alarm to real time operator for early replacement of faulty card module. | DCS will be replaced under R & M activity in the next overhauling as per the proposed annual outage plan approved by ERPC. |
| Farakka Unit 4 | Response is not adequate and withdrawal of response is not in line with IEGC. Over generation was observed due to which Primary response margin was not adequately available. | The RGMO logic and ramp down logic after RGMO operation needs tuning. | Fine Tuning of logic for RGMO will be completed by end of March 2019 |
| Farakka Unit 5 | No response has been observed | HP CV 4 is 100 % stuck so RGMO operation is not proper and desired response is not observed. | In the next overhauling (as per the ERPC approved shutdown of unit), the issue will be resolved. |
| Farakka Unit 6 | Response is not adequate | The RGMO logic and ramp down logic after RGMO operation needs tuning. | Fine Tuning of logic for RGMO will be completed by end of March 2019. |
| Kahalgaon 1,2,3&4 | Response is not adequate | The new DCS have been installed and there is a need forfine-tuning the RGMO Logic. It was informed that Boiler for the units is not responding as per the requirement envisaged response for FGMO. | NTPC intimated that by 4th Feb 2019 the fine-tuning activity would be completed |
| Kahalgaon 5,6,7 | Unit 5 has provided oscillatory response. While unit 6 and 7 has provided poor response. | Need of fine-tuning the RGMO Logic for all the units. | NTPC intimated that by 4th Feb 2019 the fine-tuning activity would be completed. |

| | | | |
|---|---|---|---|
| Talcher 1,2 | No response Observed | The DCS (ABB make) is very old. During the next overhauling, response of PSS will be tuned and other issues will be attended. | Fine-tuning of RGMO is going on and expected to be completed by Next Overhauling. |
| Talcher Unit 3,4,5&6 | Good Response in Unit 4 observed while inadequate response in other units. | Unit 3 Boiler R & M is over and tuning of RGMO is required.<br>For the units 5 and 6 , Fine tuning of RGMO logic is required. | NTPC intimated that by 4th Feb 2019 the fine-tuning activity would be completed. |
| Barh 4 &5 | Based on the submitted plots for events, it has been observed that the units may be responding during nominal frequency changes in the grid and thus adequate response has not been observed during frequency response events. | NTPC intimated that the events will be analyzed and fine-tuning will be done in the RGMO logic for complying with IEGC. | NTPC will take up the matter of data collection in .csv format with their OEM.<br><br>NTPC will calculate the FRC of units for the last three events and submit it to ERLDC by 4th Feb 2019.<br><br>NTPC will be taking up the issue of fine tuning of the RGMO with OEM. |
| MPL 1 and 2 | Response for Unit 1 is not adequate while some response is observed for Unit 2.However, withdrawal of response is not in line with IEGC. | In Unit 1 there is limitation due to Boiler issues while in unit 2 RGMO logic needs fine tuning. | Unit 1: The issue arising due to Boiler limitation has been taken up with OEM. MPL to provide the timeline for the activity to ERPC/ ERLDC.<br><br>Unit 2: Fine-tuning of RGMO will be done as Unit overhauling is underway. |
| Teesta V 1,2,3 | Based on the submitted plots for different events, it | NHPC intimated that they would fine-tune their | Due to old DCS,NHPC is not able |

| | | | |
|---|---|---|---|
| | has been observed that the units may be responding during nominal frequency changes in the grid and thus adequate response has not been observed during frequency response events. | RGMO logic for compliance with IEGC.<br><br>It was informed by NHPC that during high hydro season they will not be able to give governor response. However, detailed reason could not be provided during the meeting. | to extract the MW and frequency data in .csv format. They will take up the matter with OEM.<br><br>NHPC will calculate the FRC of units for the recent events and submit to ERLDC/ERPC.<br><br>NHPC will be taking up the issue of fine-tuning of the response with OEM.<br><br>NHPC will provide a detailed explanation with reason on the statement on no response during high hydro season. |
| BRBCL 1 & 2 | Slow Response has been observed based on the data. | NTPC intimated that they would check the reasons for the poor response and action will be taken for improving the governor response. | NTPC Intimated that tuning of RGMO logic will be taken up with OEM. |
| Teesta 3 1, 2, 3, 4, 5, & 6 | Response is observed | Fine-tuning of RGMO logic will be done. | Teesta 3 will be doing the fine tuning of RGMO logic and will intimate ERLDC/ERPC. |
| GMR 1, 2 & 3 | GMR Units are responding however, the response is slow. | No representative from GMR attended the meeting. | |
| JITPL 1 & 2 | Poor Response has been observed. | No representative from JITPL attended the meeting. | |
| Adhunik 1 & 2 | Response is observed however, withdrawal of response is fast. | No representative from Adhunik attended the meeting | |

| | | | |
|---|---|---|---|
| Dikchu | Response is observed but slows in nature. | No representative from Dikchu attended the meeting. | |

**B. State Generators**

| | | | |
|---|---|---|---|
| Tenughat 1, 2 | No details for analysis of Governor Response. | TTPS intimated that Unit 1 is having new DCS (Nov'16) so data retrieval is possible as will be submitted.The unit earlier was running at de-rated power (160 MW)due to issues. Presently Unit overhauling has been completed however,it is kept out.<br><br>Unit 2is having old DCS and the unit is under RGMO. | Tenughat was intimated to submit the data for the events in order to analyze the response of TTPS units. |
| Mejia (1, 2 ,3, 4) , Mejia A (5 & 6), Mejia B (7 & 8) - DVC | Response has been observed in units however, it did not sustain and was withdrawn within 10-15 seconds. | The fine tuning of RGMO is required. | DVC intimated that they are going to have an internal meeting and will intimate the reason for the inadequate response and action plan by 5/2/19 |
| Koderma 1 & 2 - DVC | Response has been observed in units however, it did not sustain and was withdrawn within 10-15 seconds. | Unit 1: It is operated with valve wide open due to issue with boiler pressure.<br>Unit 2: Similar to Unit 1 but has been attended during overhauling. Fine-tuning of RGMO logic is required. | |
| Chandrapura B (1 & 2) -DVC | Response has been observed in units however, it did not sustain and was withdrawn within 10-15 seconds. | CTPS explained that the inadequate response could be due to several reasons.However when asked about event wise details and similar issues observed in all DVC units, DVC explained that they will provide the details after internal discussion. | |

| | | | |
|---|---|---|---|
| Bokaro A () & B(U 3)-DVC | Response has been observed in units however, it did not sustain and was withdrawn within 10-15 seconds. | | |
| Durgapur 1 & 2 - DVC | Response has been observed in units however, it did not sustain and was withdrawn within 10-15 seconds. | | |
| Waria 4-DVC | No Response has been observed. | | |
| OHPC (All Eligible Hydro Units : Balimela, Indravati, Upper Kolab, Rengali ) | Most of the units have not responded for the events | OHPC intimated that they have kept all the units in FGMO with Manual intervention. The record for manual intervention and response during the events, criteria for manual intervention were not presented during the meeting. | OHPC to submit the operational philosophy, Reason for keeping FGMO with manual intervention for all units, Criteria of initiating the manual intervention and proper records of Manual intervention and obtained response to ERLDC/ERPC. |
| IBTPS 1, 2 | RGMO response could not be analyzed due to absence of data. | IBTPS intimated that RGMO is in service. | OPGC to be submit the details of response for IBTPS units for validating the FGMO operation during the events by 4th Feb 2018. |
| DPL 7, 8 | Response was observed however the withdrawal of response was not in line with IEGC. | DPL intimated that fine tuning of RGMO logic is required | DPL will be submitting the action plan by 5/2/19 |
| Budge Budge 1,2 | No response has been observed from these units. | Units are under FGMO with Manual intervention.However, units are generating above its full capacity for catering the utility load. | CESC wasadvised that as per IEGC, the margin for primary response has to be kept in the units. |
| Budge Budge 3 | Response was observed however the withdrawal of response was not in line with IEGC. | CESC informed that there was an error in the RGMO logic, which has been corrected and further fine- | CESC intimated that fine-tuning of RGMO logic would be done with OEM during next |

| | | | |
|---|---|---|---|
| | | tuning is required. | overhauling |
| Kolaghat 1, 2, 3, 4 & 5 | No response is being observed | All units of Kolaghat are having Hydro mechanical governorand so cannot be run in RGMO. It was informed that all the units are kept in FGMO with Manual intervention | WBPDCL was advised that CERC hasn't exempted any generator from FGMO/RGMO. Manual intervention is for LMZ units and for units that cannot be run with RGMO, they can opt for FGMO. |
| Sagardighi 1,2,3,4 | No response is being observed. | Units are in RGMO. However reason for no response will be analyzed and submitted to ERPC/ERLDC/SLDC. | WBPDCL will analyze the reason for no response and submit the same along with action plan to ERLDC/ERPC by 4th Feb 2019. |
| Bakreshwar1,2,3,4 ,5 | No response is being observed. | For Unit 1, 2, 3 and 4 RGMO has been kept in service. While due to Boiler issue, the RGMO of Unit 5 has been kept out of service. 1 second data are not available for unit 1, 2 & 3. the DCS system will be replaced in 2020-21 (Unit#2), 2023-24 (unit#1), 2022-23(Unit#3). | WBPDCL will analyze the reason for no response and submit the same along with action plan to ERLDC/ERPC by 4th Feb 2019. |
| Santaldih 5 & 6 | | RGMO is kept out of service. RGMO for unit 6 can be taken in service while for unit 5 it will be decided after unit overhauling. | WBPDCL will inform ERLDC/ERPC regarding the action plan by 4th Feb 2019. |

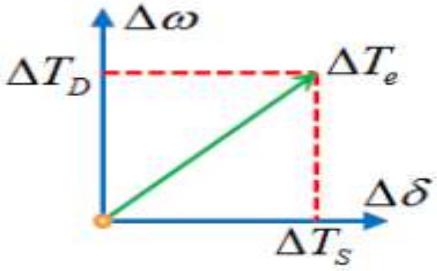
# Power System Stabilizer and Need for its Tuning

# Power Swing

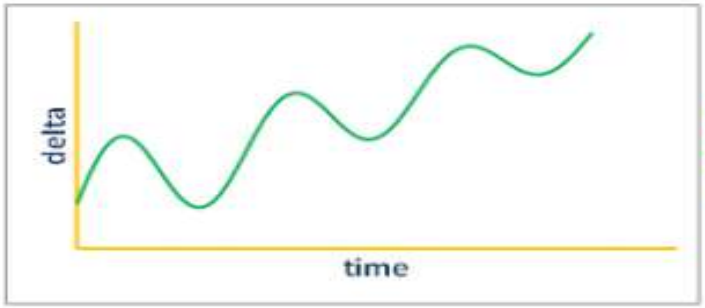
- **Generator have synchronizing and damping torque.**
  - **Synchronizing Torque $T_s$ : Keeping Synchronism after Large Disturbance (Transient Stability)**
  - **Damping Torque $T_d$ : Damping after small Perturbation (Small Signal Stability)**
- **Adequate Ts and Td to keep generator stable and maintain synchronism with the grid.**
- **Power Swing refers to oscillation in active and reactive power flows on a transmission line consequent to a disturbance.**

# Power Swing…

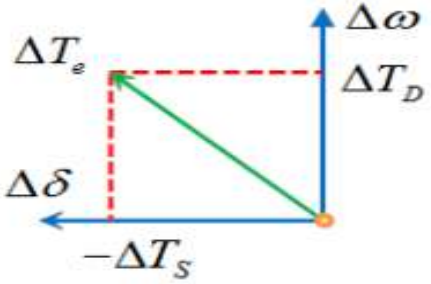

Stable
- Positive $T_S$
- Positive $T_D$



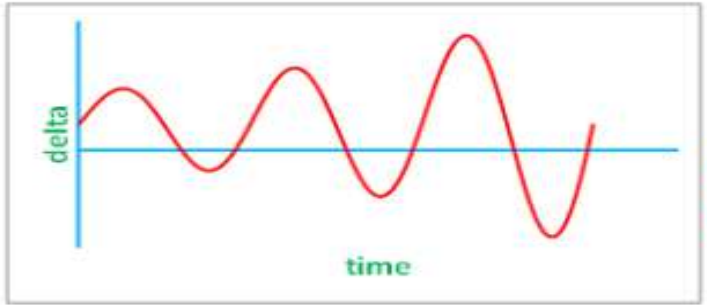

(a)



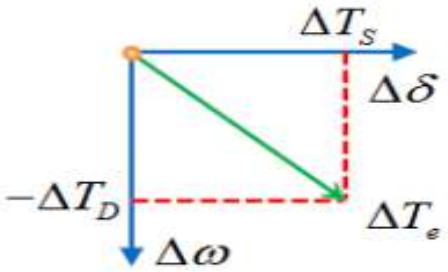

Non-oscillatory Instability
- Negative $T_S$
- Positive $T_D$




(b)



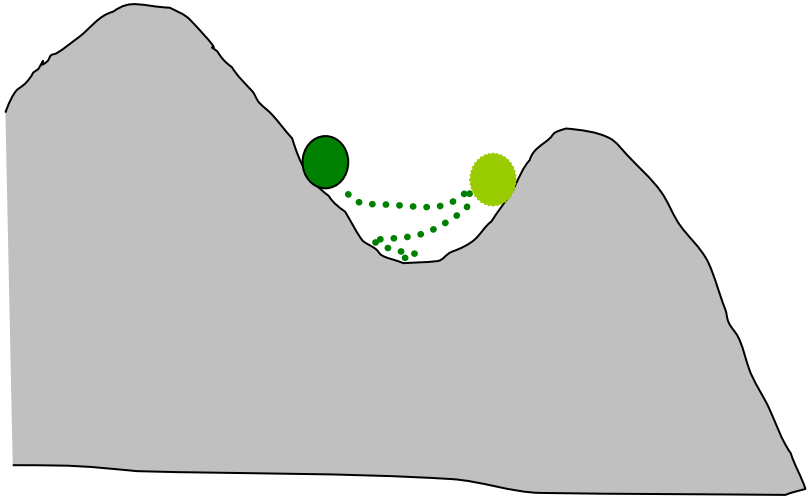

Oscillatory Instability
- Positive $T_S$
- Negative $T_D$



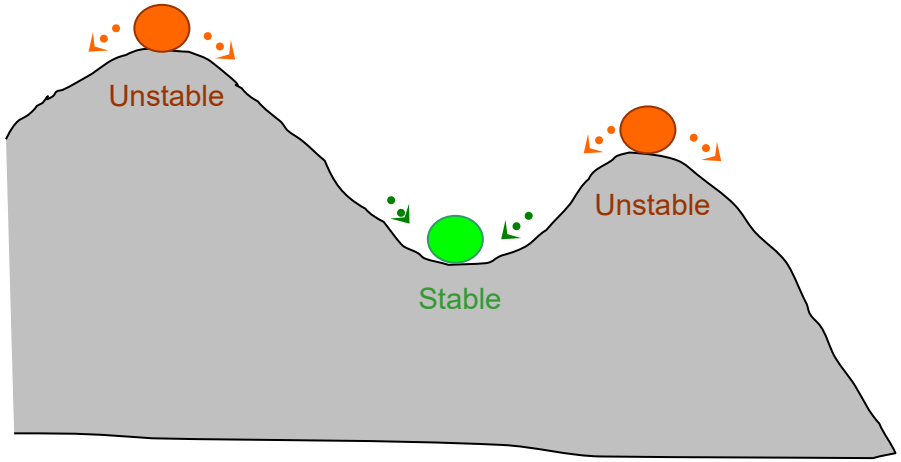

(c)

***Source : NPTEL***

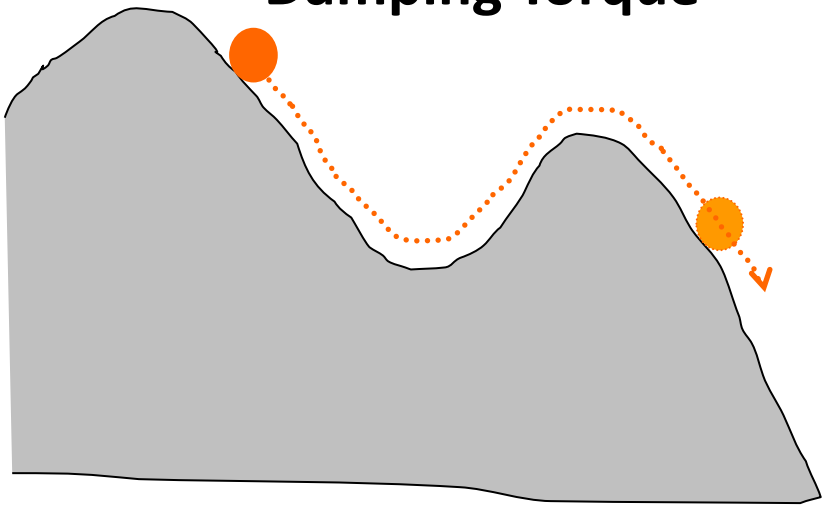
# Power Swing…



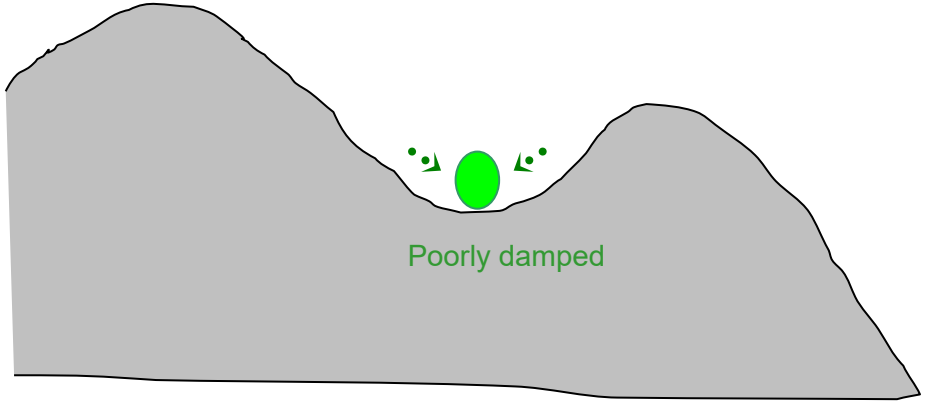
Adequate Synchronizing and Damping Torque




Lack of Synchronizing Torque



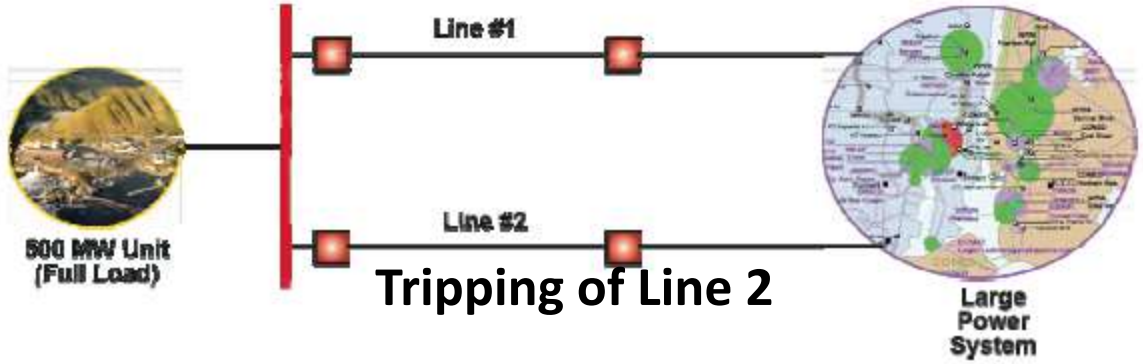
Lack of Synchronizing Torque



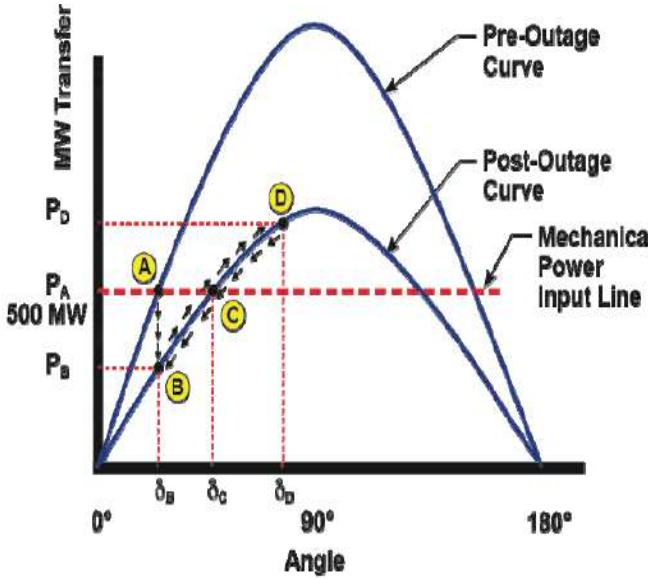

Lack of Damping Torque

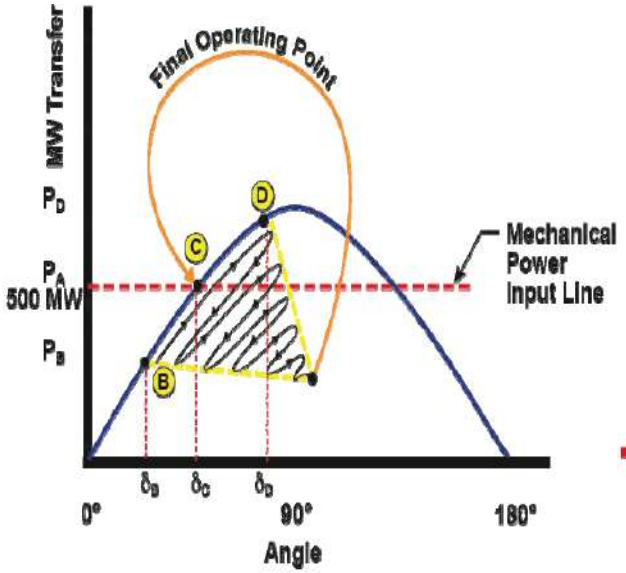
*Source : Slides from Presentation by Prof.* Mani Venkatasubramanian, WSU

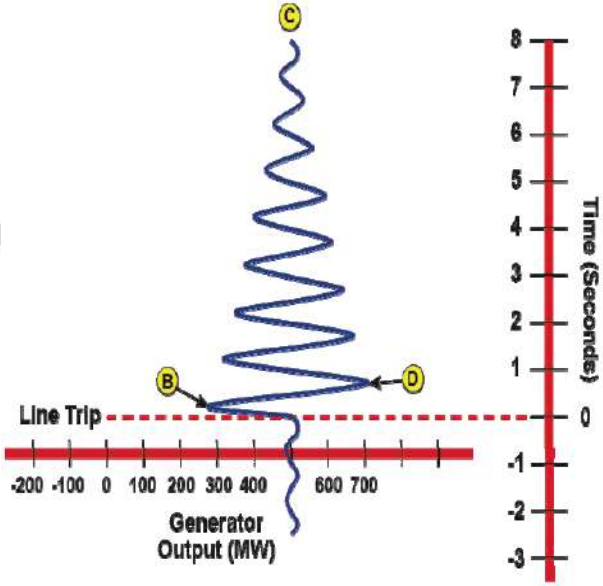
# Power Swing…




**Tripping of Line 2**



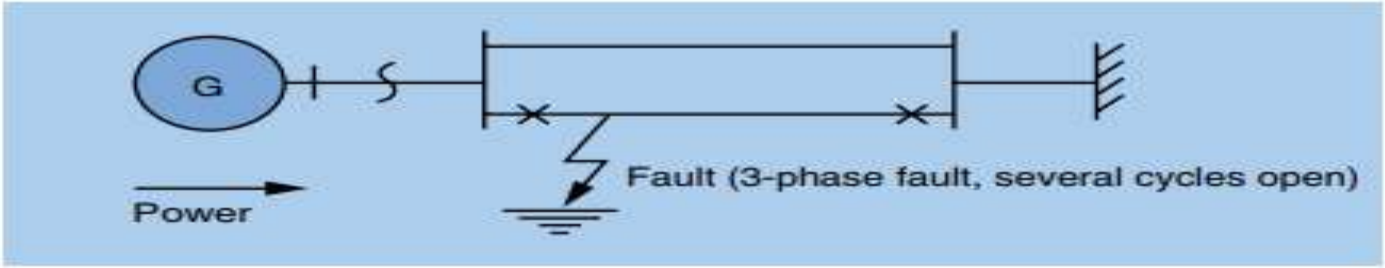



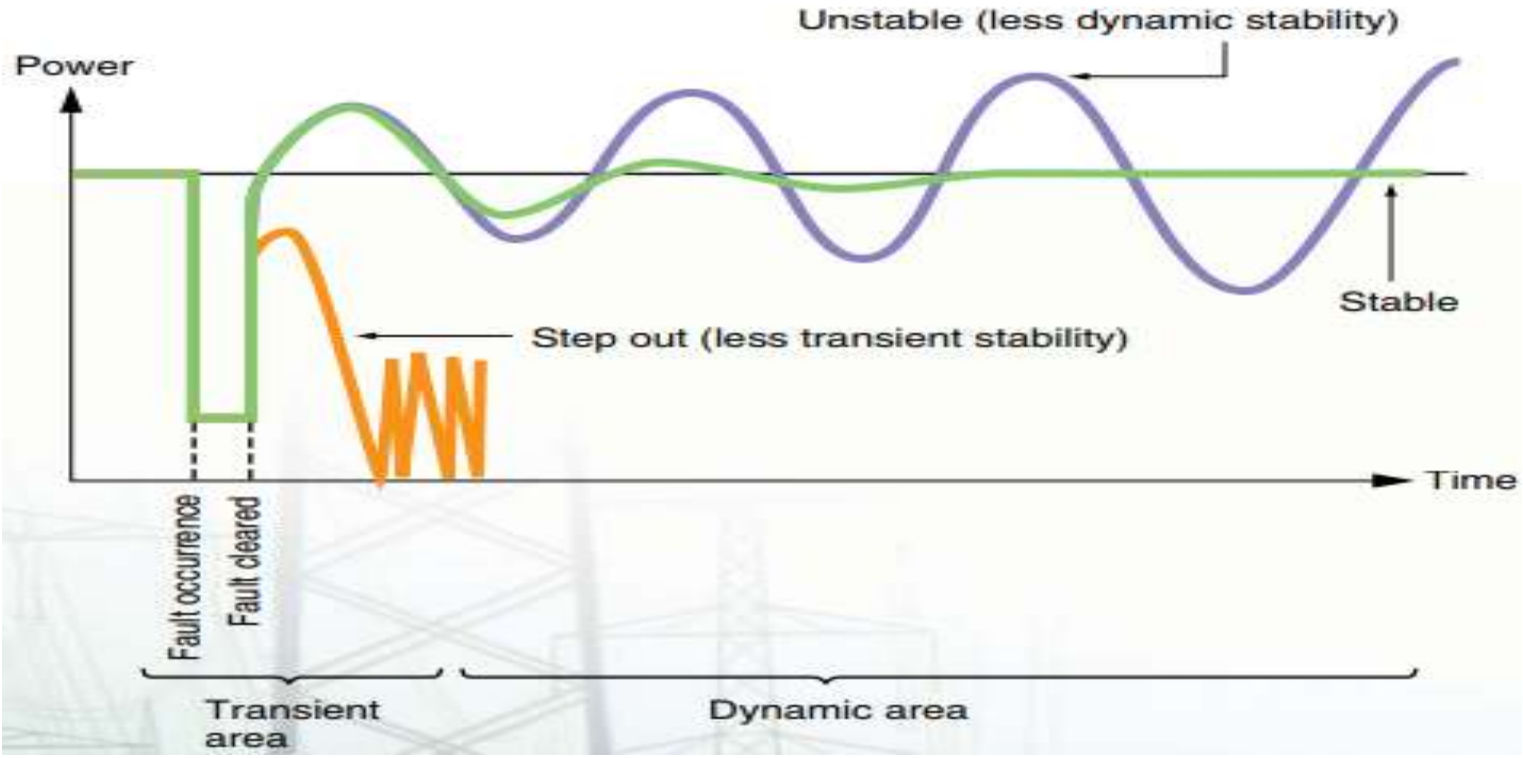




## Adequate Damping and Synchronizing Torque

*Source : EPRI-Power System Dynamic Tutorial*

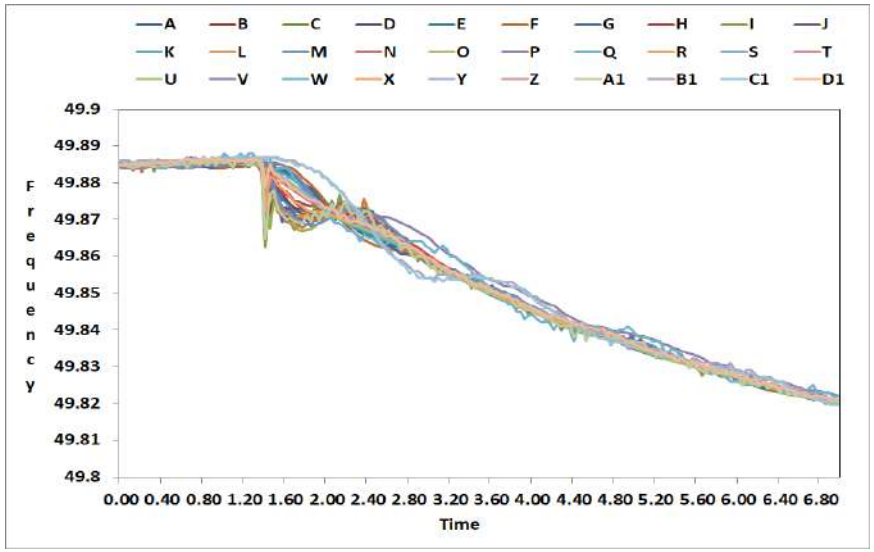
# Power Swing…



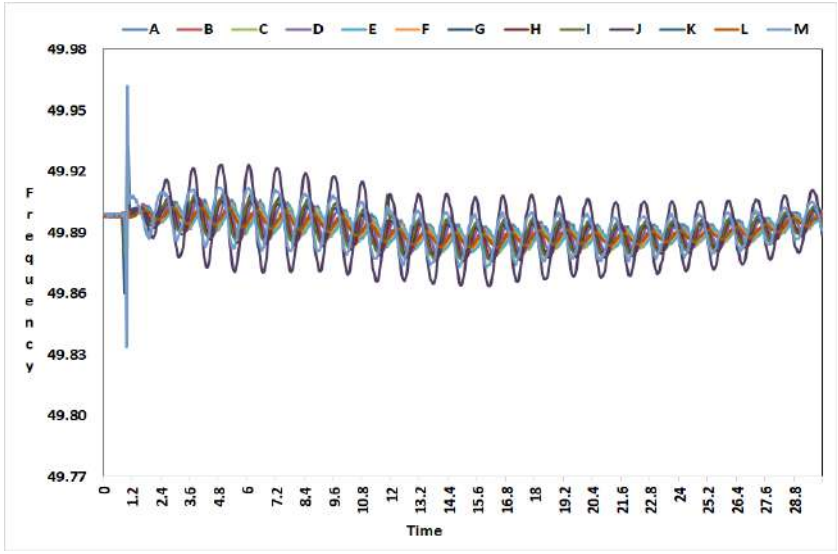




*Source : http://www.meppi.com/Products/GeneratorExcitationProducts/Static%20Excitation%20System/Power%20System%20Stabilizer.pdf*

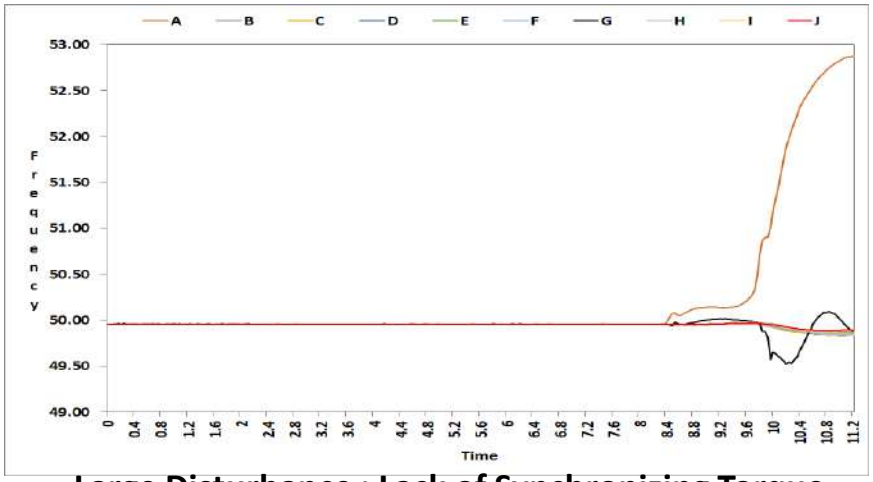
# Power Swing…




**Large Disturbance**
**Adequate Synchronizing and Damping Torque**
**Stable Swing**



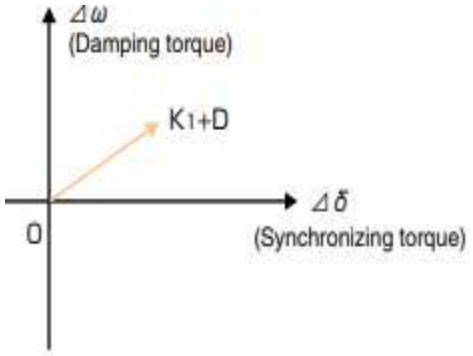

**Small Disturbance**
**Adequate Synchronizing but Low Damping Torque**
**Low Frequency Oscillation (Low Damping)**



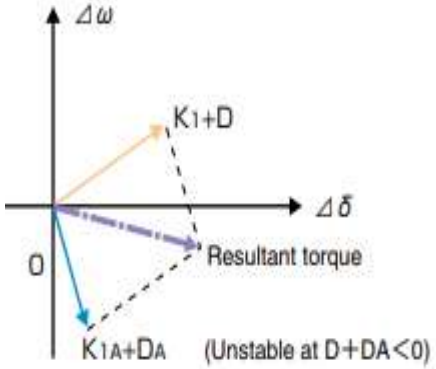

**Large Disturbance : Lack of Synchronizing Torque**
**Out of Step/Unstable Swing**

# Role of Automatic Voltage Regulator

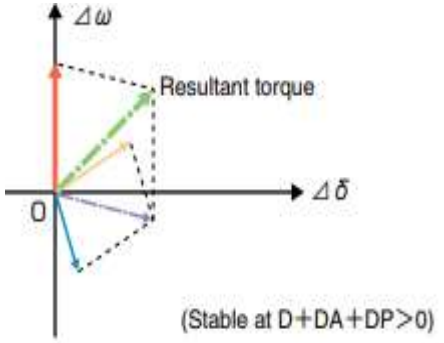
- **AVR :** Fast Acting AVR results in Improvement in Transient stability (Improve Synchronizing Torque) However provide a **weakening effect to Damping Torque**.




Constant Excitation




Fast Acting AVR



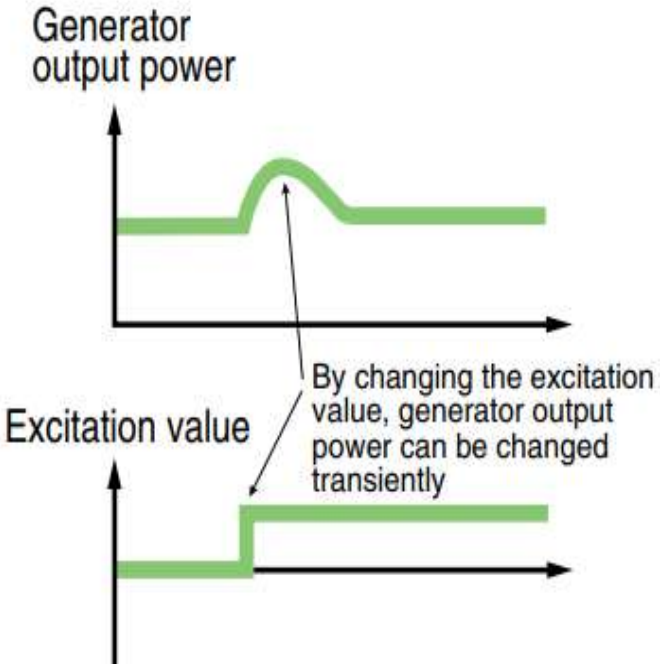

AVR +PSS

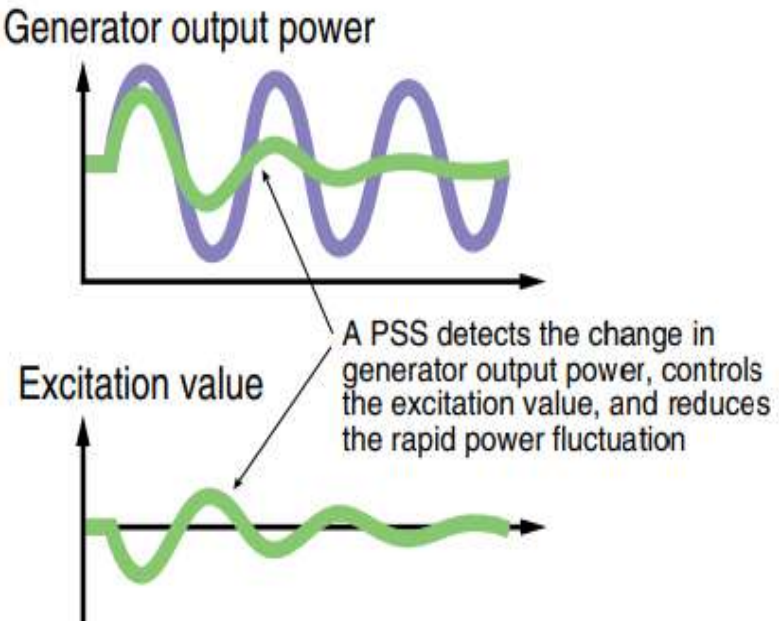
*Source : http://www.meppi.com/Products/GeneratorExcitationProducts/Static%20Excitation%20System/Power%20System%20Stabilizer.pdf*

# Role of Power System Stabilizer

- Additional Input to AVR to improve Damping Torque.
- Used to **minimize real power oscillations** by rapidly adjusting the field of the generator to dampen the low-frequency oscillations.
- PSS input has **appropriate phase and gain compensation** to modulate field voltage such that torque are generated that are out of phase causing Low frequency Oscillation.

# Role of Power System Stabilizer…




- Generator output power is decided by a turbine's mechanical torque.
- Can be changed by transiently changing the excitation value

- PSS detects the change in generator output power, controls the excitation value, and reduces the rapid power fluctuation

*Source : http://www.meppi.com/Products/GeneratorExcitationProducts/Static%20Excitation%20System/Power%20System%20Stabilizer.pdf*

# Regulation: PSS and Its Tuning

## 1. Definition of PSS :

**CEA (Technical standards for connectivity to the Grid) Regulation, 2007:** Power System stabiliser means controlling equipment which receives input signal of speed, frequency and power to control the excitation via the voltage regulator for damping power oscillation of a synchronous machine".

# Regulation: PSS and Its Tuning…

## 2. Provision of PSS :

- **CEA Technical Standard for Construction of Electrical Plants and Electric Lines**
  - For Coal or lignite based Thermal Generating Stations (10.2. g.i: )
  - For Hydro power Plan (37.3.e)
- **CEA (Technical standards for connectivity to the Grid) Regulation, 2007**
  - For New generating Units (part II. 1. C)
  - For Old Units: (part II. 2. 2):
- **Standard technical features of BTG system for supercritical 660/ 800 MW thermal units, CEA, July 2013 (16.2.4.iii.d.5)**
- **Standard technical specification for main plant package of sub- critical thermal power project 2 X (500 MW or above), CEA, Sept 2008 (5.2.4.iv)**

- **New Thermal/Gas/Hydro plant : > 100 MW must have PSS along with AVR.**
- **For old Thermal/Hydro Power plants commissioned prior to 2007: > 100 MW must provide AVR and PSS during their renovation and modernization.**

# Regulation: PSS and Its Tuning…

## 3. PSS Tuning :

- **IEGC 5.2.k:** Power System Stabilizers (PSS) in AVRs of generating units (wherever provided), **shall be got properly tuned by the respective generating unit owner as per a plan prepared for the purpose by the CTU/RPC from time to time.** CTU /RPC will be allowed to carry out checking of PSS and further tuning it, wherever considered necessary.
- **CEA (Technical standards for connectivity to the Grid) Regulation, 2007 6.g**: The requester and user shall cooperate with RPC and appropriate Load despatch centre in respect of matter listed below, but not limited to: **Cooperate with RPC for tuning of PSS provided in the excitation system of generating Unit.**

# Report of the Task Force on Power System Analysis under Contingencies

**Recommendation :** Necessary exercise to retune PSS should be undertaken at interval of 3-4 years or even earlier depending on network additions in vicinity of specific generators.

# PSS Tuning Requirement

A. The PSS gives improved damping following a step change in voltage.

B. Any oscillations are damped out within 2 cycles.

C. The PSS gives improved damping of frequencies in the band 0.02 – 4 Hz.

D. The gain margin test demonstrates no appreciable instability at 3 times proposed gain.

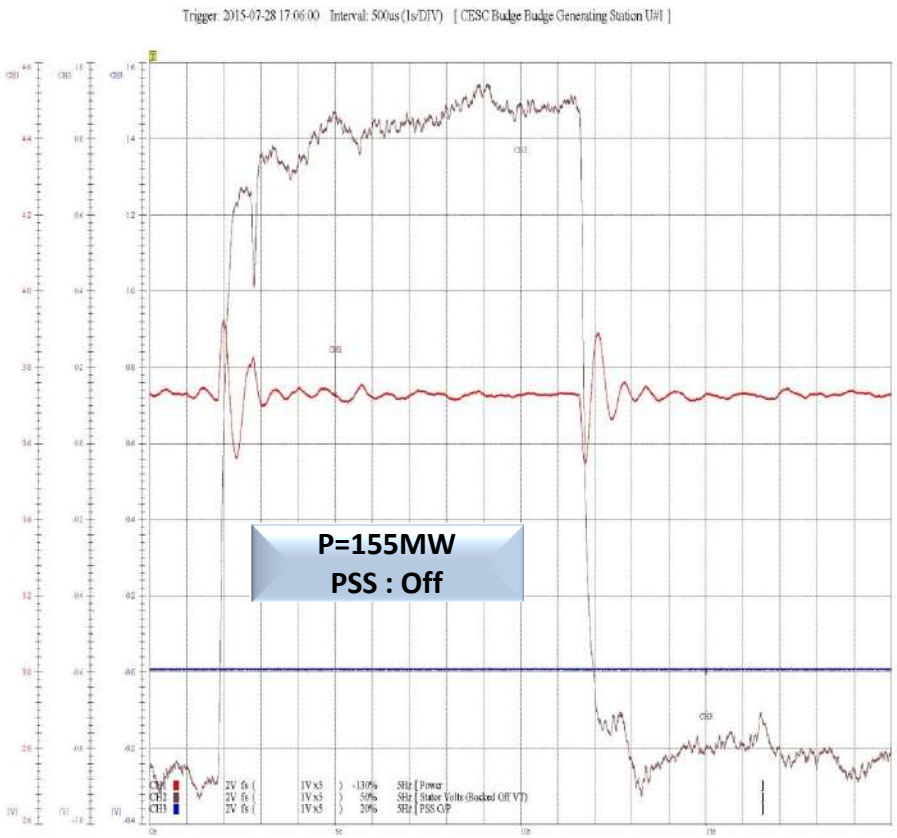
E. PSS has to perform for under variable system operating condition (Real and reactive Power and Terminal voltage) and network topologies by varying the system impedance (15 %< X <50 %).

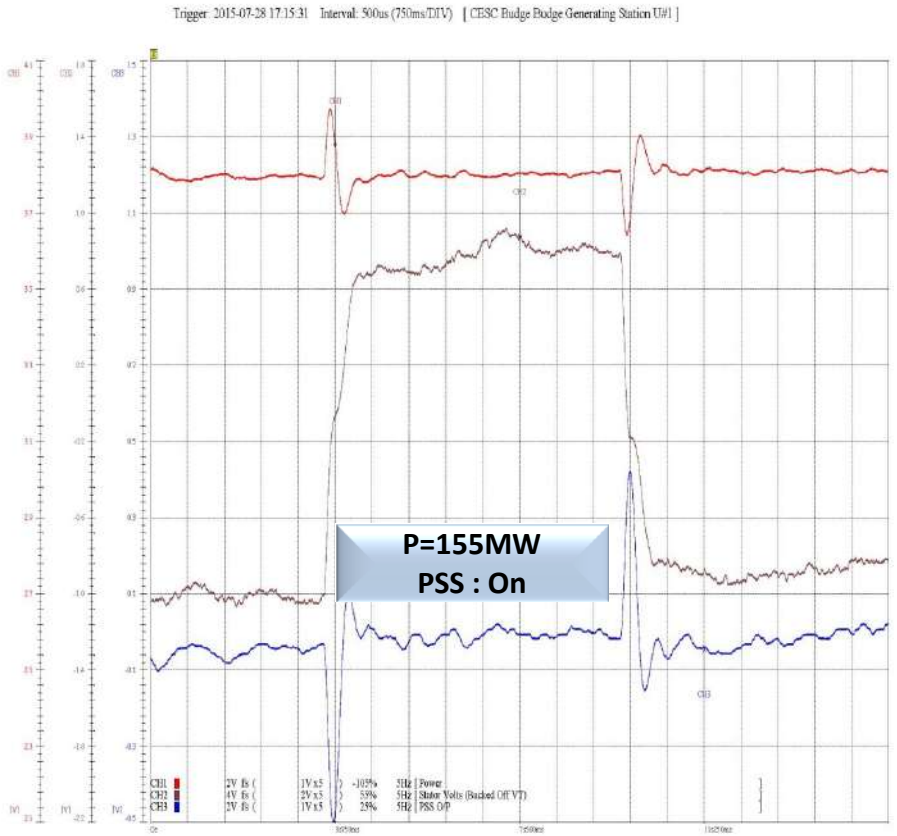
F. PSS has to perform and adequately damp oscillation after the short circuit as for a duration defined in CEA transmission planning Criteria 2013 on the directly connected lines from the generating station

G. PSS should not be interacting negatively or having any adverse impact on the torsional mode of the generator (Applicable for Large Steam Turbine generating unit on single shaft units)

# PSS Tuning in Eastern Region

## Budge Budge

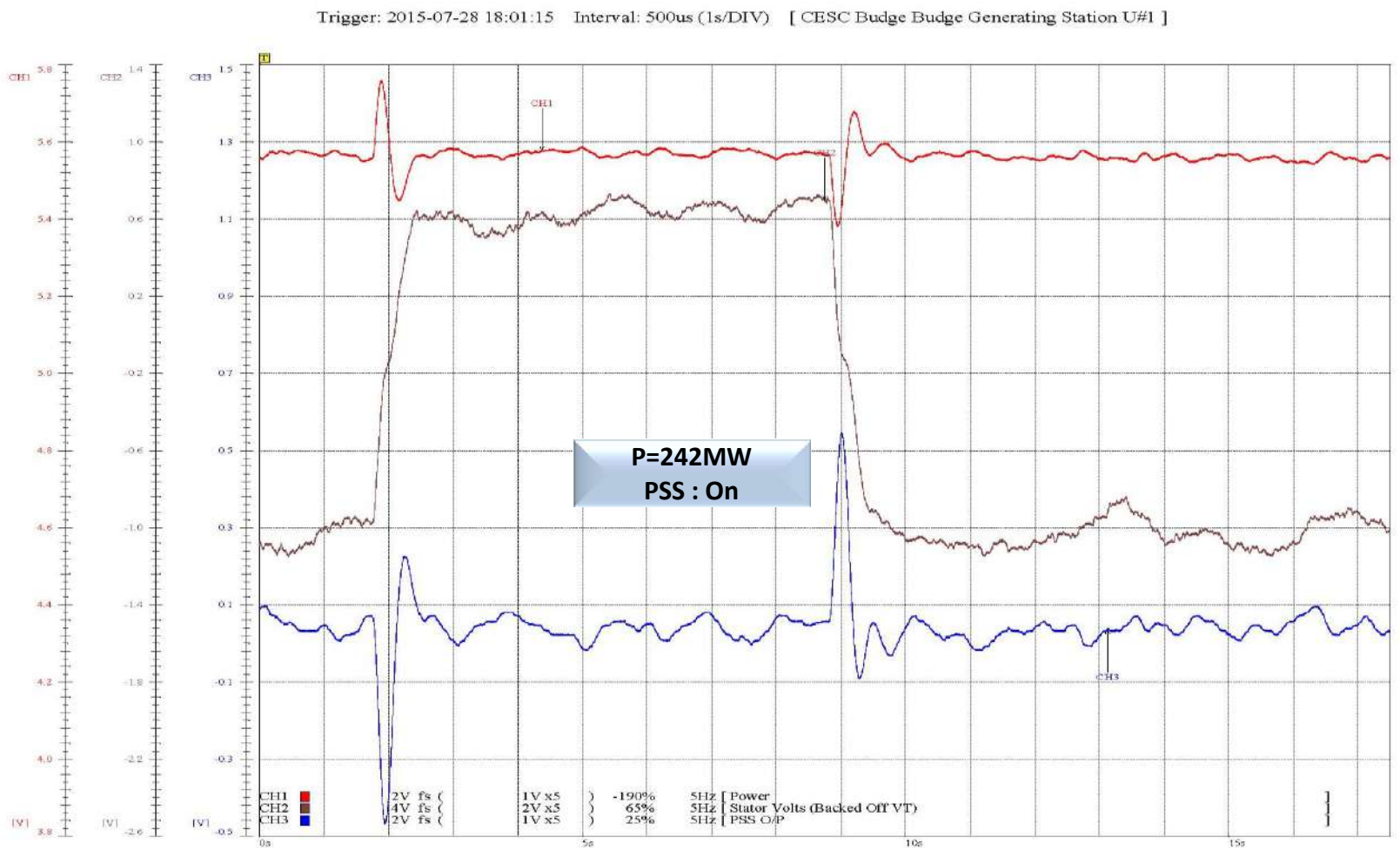



**Step Test 2 % : Partial Load**

***Source : CESC***

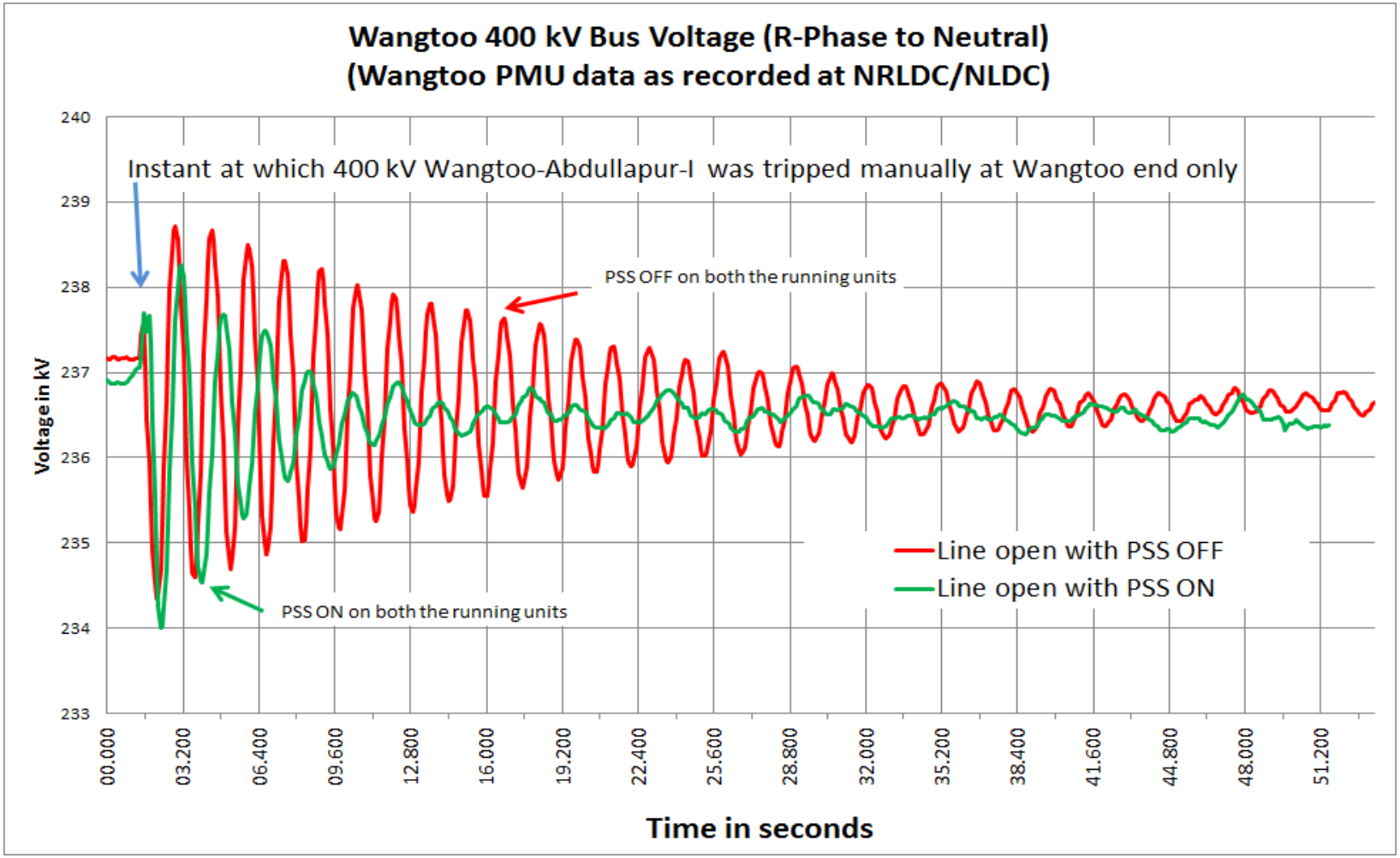
# Budge Budge




## Step Test 2 % : Full Load

*Source : CESC*

# Karcham Wangtoo




## Contingency

***Source : NRLDC***

# Simulation With Field Data

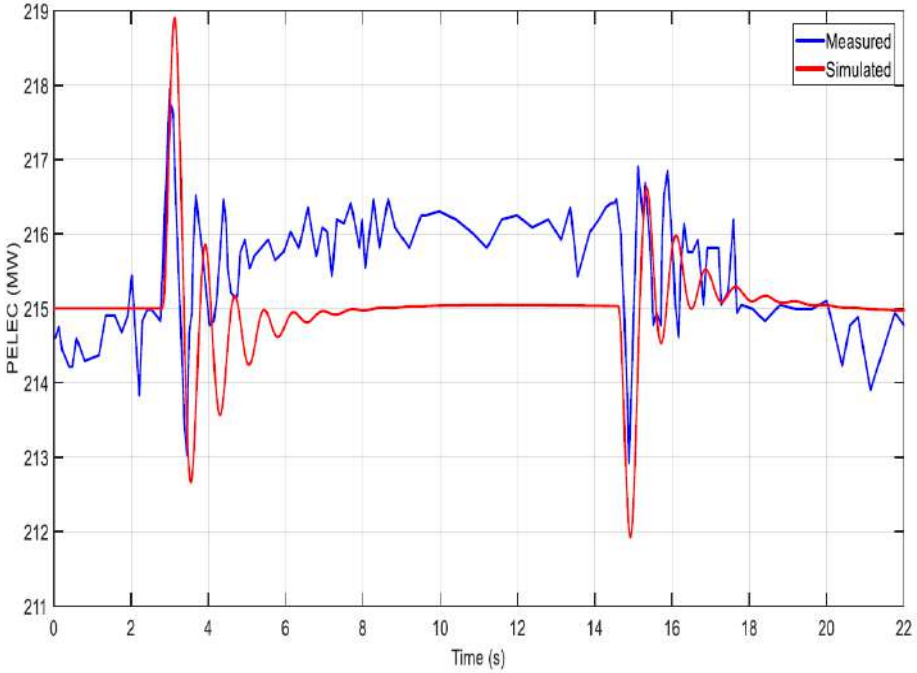



Figure 11: Response of active power to 4% step online with PSS On

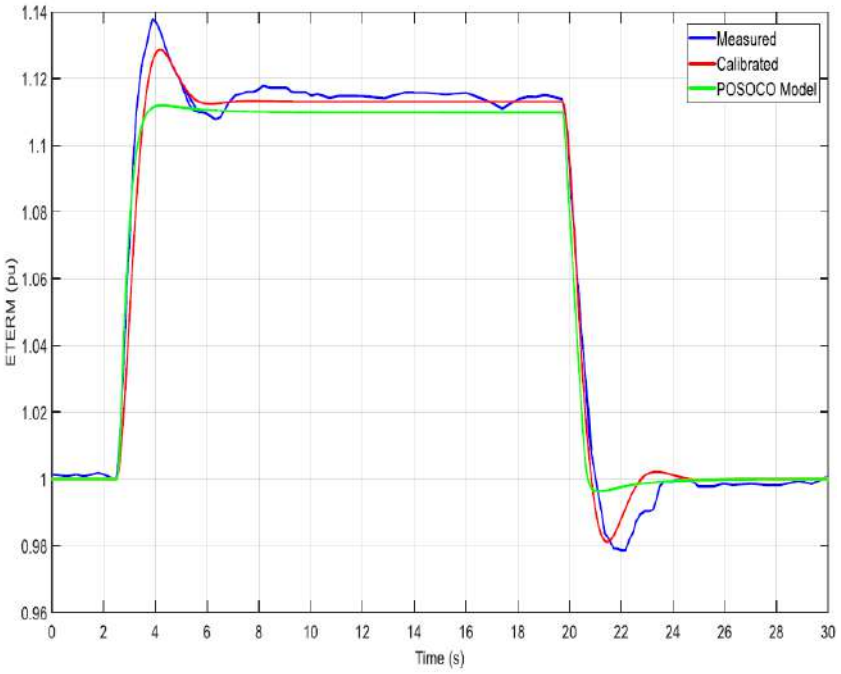



Figure 10: Response of terminal voltage for AVR offline step response +12%

**With the help of the data provided by the Generator, Actual Response can be reproduced from Simulation**

**Helps in Accurate Transient and Dynamic Study**

# Supporting Slides

# Reasons for LFO Observed in the Indian Grid

- Operating with Weak Tie Line at high loading limits.
- Weak Interconnection in the system.
- Generating Plant operating with high angular separation from adjacent node.
- Generator Control System Software Problem.
- Issue with Governor System for Generating Unit.
- Generator Testing like governor, ramp test(PG test)
- Switching of transmission element causing large voltage change.
- Severe Fault /Delayed Fault clearance.
- Mal-operation of over speed limiting Gear Mal-operation of over speed limiting gear.
- Emergency stop and control valve issue during operation.
- Generating Unit synchronization and desynchronization.
- **etc.**

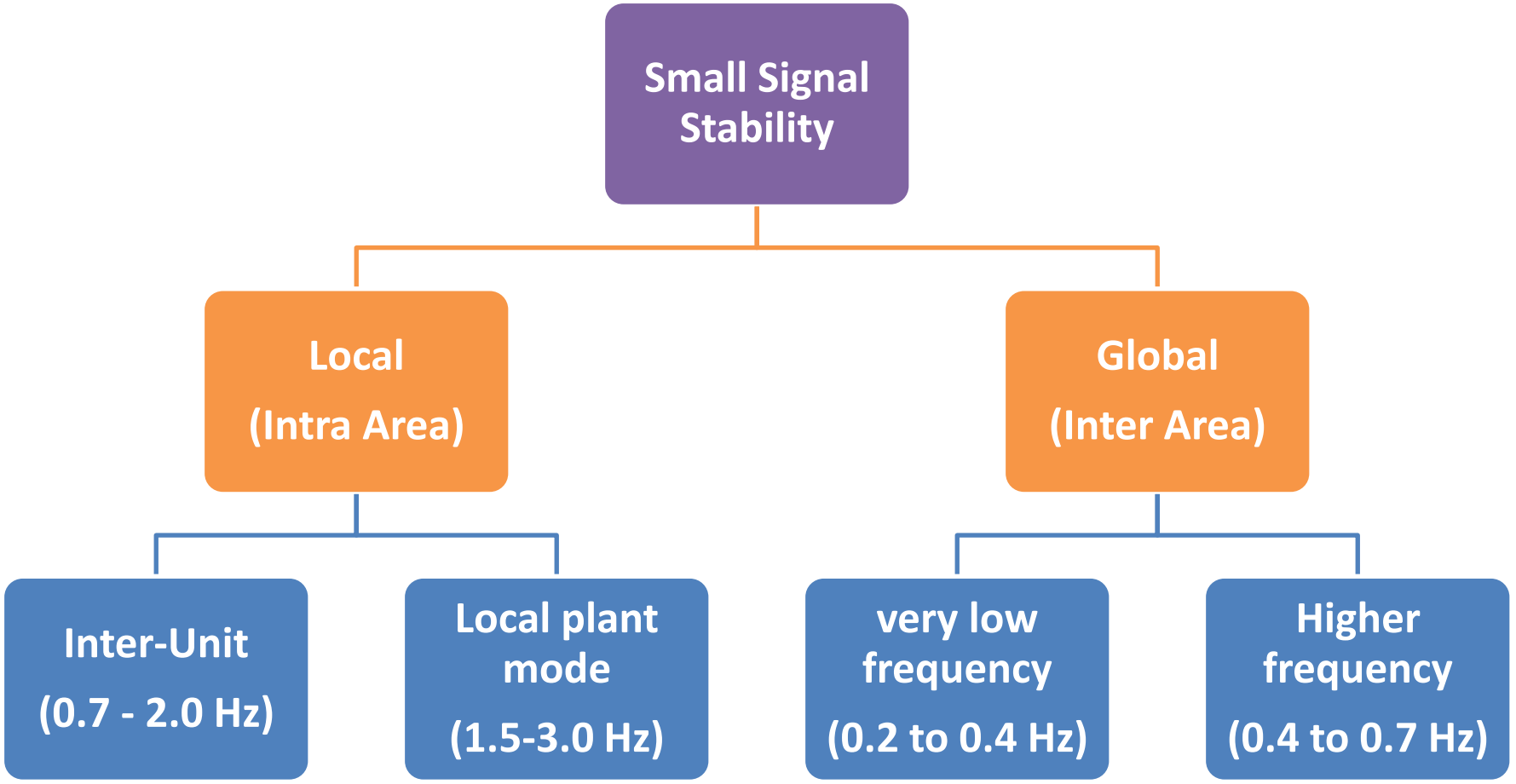
**We cannot AVOID/STOP the above reasons**

**However, We can improve the System Damping**

# Impact of LFO Indian Grid

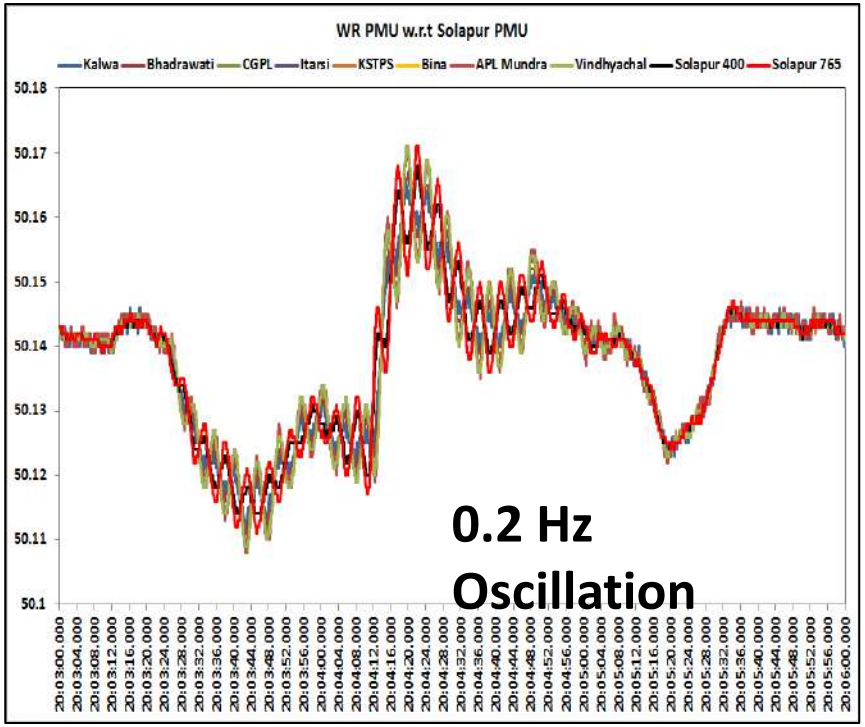
- **Tripping of Transmission line/Generating unit on unwanted operation of protection.**
  - e.g.: Tripping of APML Tirora Units/JP Nigrie Units
- **Reduction of Transfer capability of Transmission system.**
  - e.g. : WR-SR ATC/TTC was lower due to LFO.
- **Wear and tear of Generator Rotor shaft and reducing their life (Hidden Failures)**
- **Wear and Tear of Consumer rotating loads and reducing their life (Hidden Failures)**
- **Wide Scale Blackout.**
  - e.g.: Cases of blackout in NER grid.

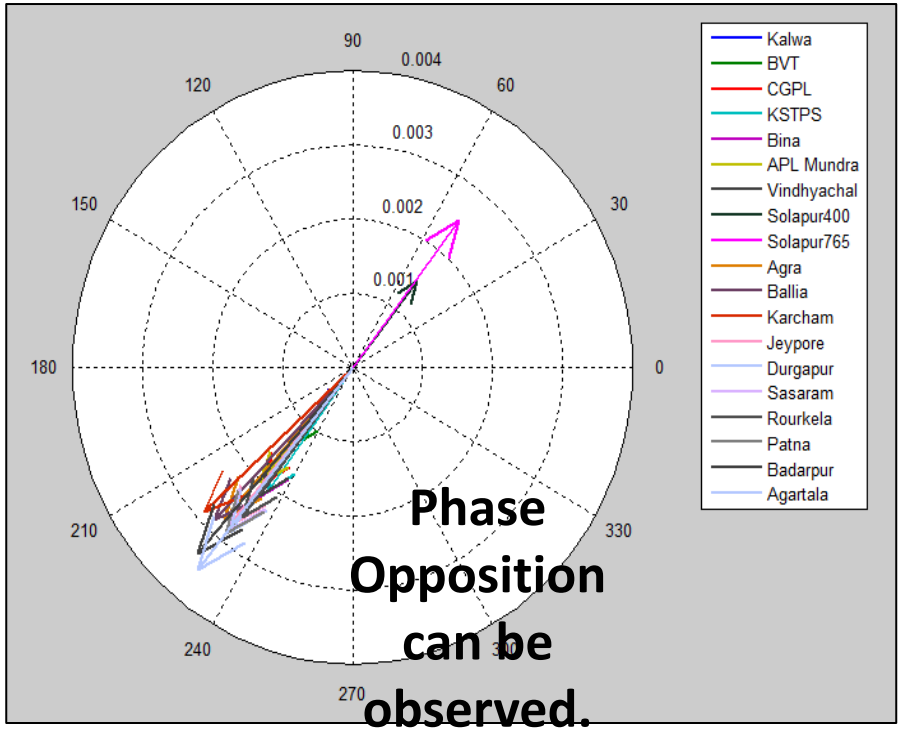
# Low Frequency oscillation Classification : Observability



# Inter –Area Oscillation : 0.2 Hz in NEWS Grid

- Here all generators align in two groups
- Two groups oscillate in phase opposition with each other.
- Major reason is weak tie link between two grids.
- E.g. 0.2 Hz oscillation between NEW and SR grid after synchronization through 765 kV Solapur-Raichur 1 circuit.

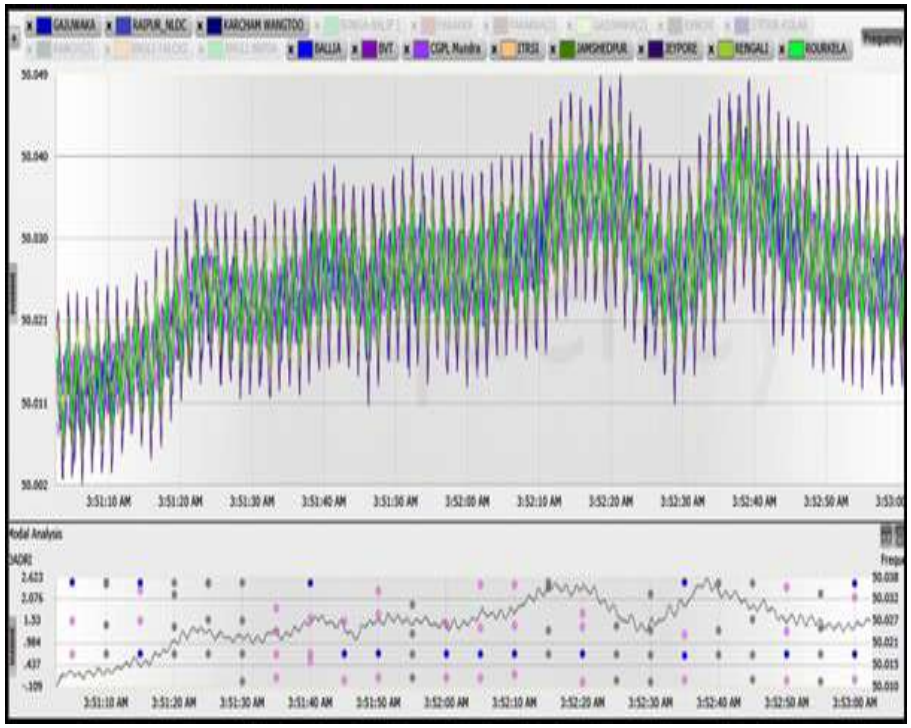


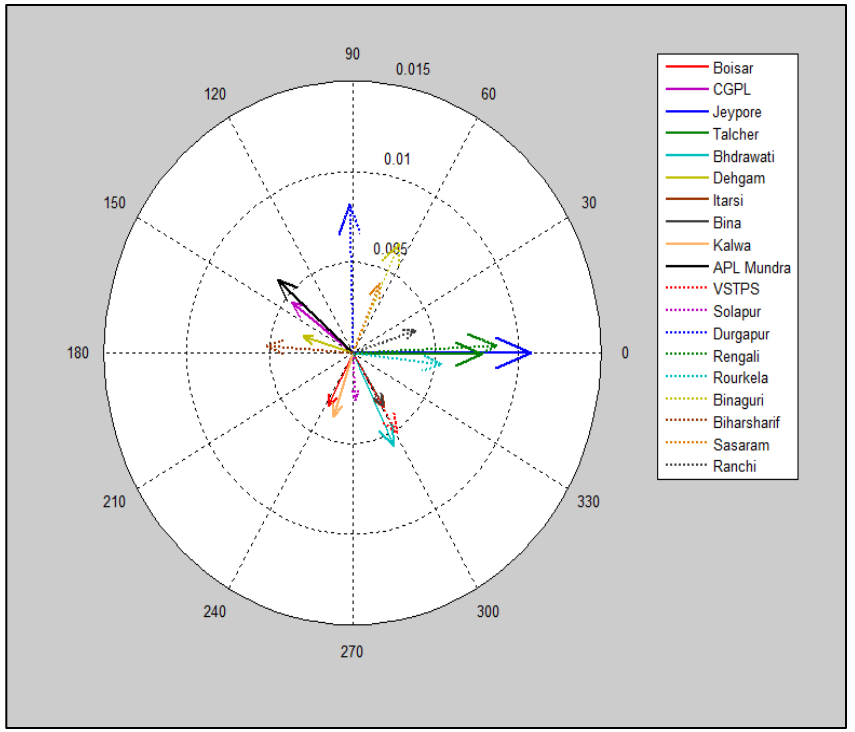




*Source : POSOCO report, Low Frequency Oscillation in Indian Grid*

# Intra –Area Oscillation : 0.56 Hz Observed between Eastern, North Eastern and Western grid

- Here few generators in one area oscillate w.r.t generators in other areas.
- Not all generators in grid participate.
- E.g. 0.56 Hz LFO between Eastern, North Eastern and Western Grid observed on 9th -11th August 2014.

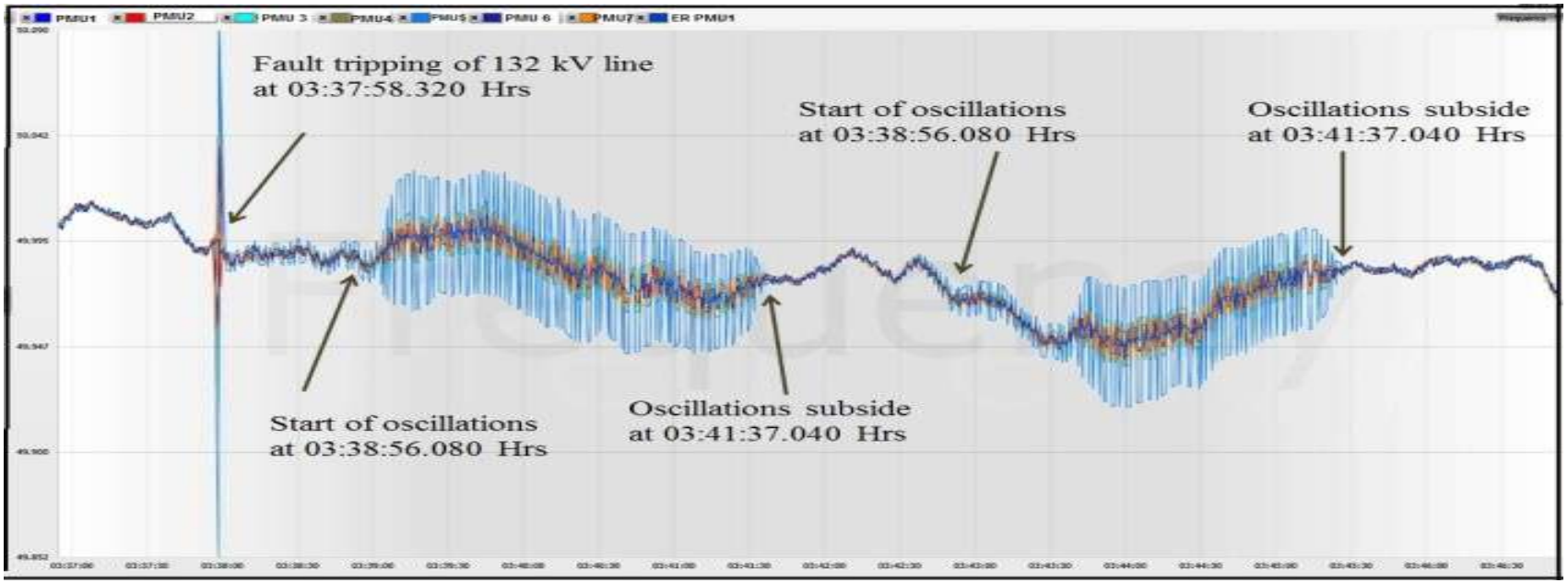





*Source : POSOCO report, Low Frequency Oscillation in Indian Grid*

# Inter and Intra Plant Oscillation : 1.2 Hz and 2.4 Hz oscillation in NER Grid

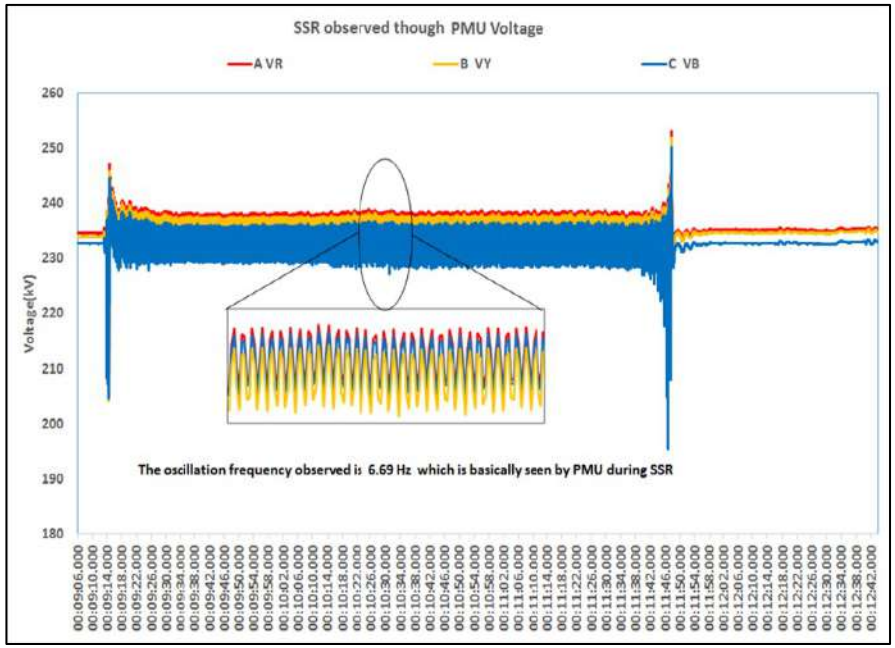
- **Inter-plant and Intra plant in general comes simultaneously. (Local mode)**
- **Intra-Plant : Unit oscillate w.r.t. other units in plant**
- **Inter-Plant : One generating plant oscillate w.r.t Grid.**
- **E.g. 1.2 and 2.4 Hz oscillation observed in NER Grid.**

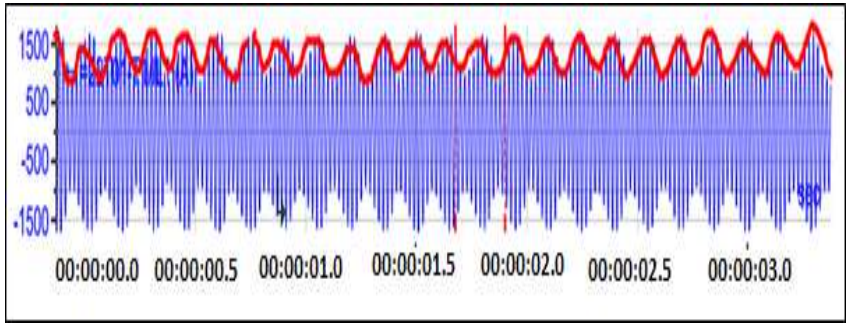


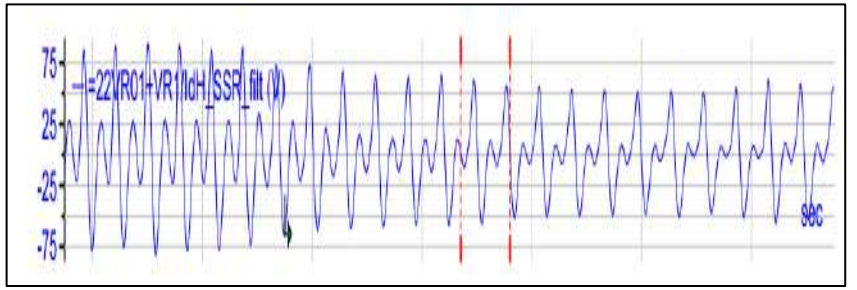

*Source : POSOCO report, Low Frequency Oscillation in Indian Grid*

# Torsional Oscillation: SSTI at HVDC Mundra.

- **Frequency range : 10-40 Hz.**
- **Reason : FSC connected line at a generator, HVDC converter at Generating plant ,Wind turbines**
- **Directly impact rotor of a generator.**
- **Dangerous for generating plant as can damage the rotor of Units**
- **Observed at KSK ( FSC connected line), APL Mundra ( HVDC Converter terminal)**



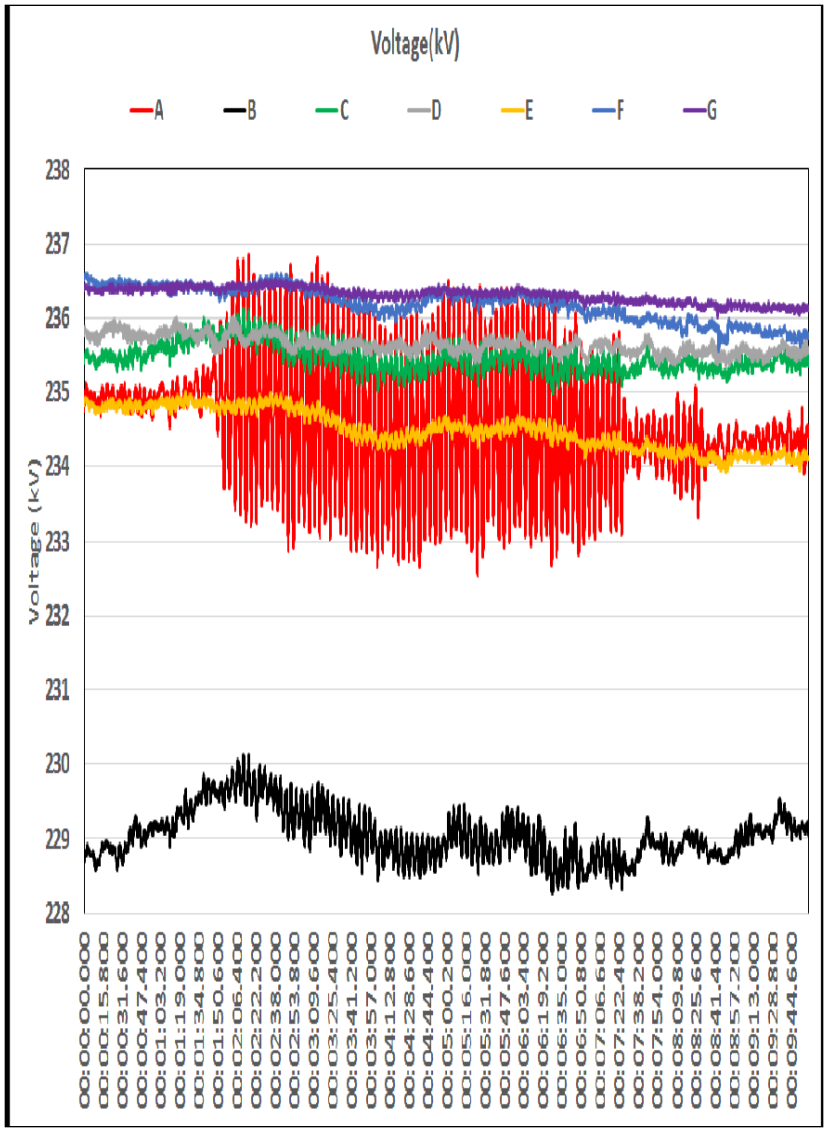




*Source : POSOCO report, Low Frequency Oscillation in Indian Grid*

# Low Frequency Oscillation at Nuclear Power Station

- Oscillation detected at Nuclear Power Plant.
- Observability : Voltage and Reactive power
- Contacted the generating unit and reason was found out in real time.
- Reason : One Emergency stop and control valve (ESCV) was leaking and when load was shifted on other, controller caused hunting.




*Source : POSOCO report, Low Frequency Oscillation in Indian Grid*

*Thank You*

| Power Plant | Unit No | Type of Exciter | Exciter Model and Vendor | IEEE Model of Exciter | PSS Model | PSS single input or dual input | PSS in Service (Yes/No) | PSS tuned (Yes/No) | Last PSS Tuning Date | Report Submitted (Yes/No) |
|---|---|---|---|---|---|---|---|---|---|---|
| **West Bengal** | | | | | | | | | | |
| Kolaghat-WBPDCL | 1-3 | Static | BHEL | ST5A | PSS 3B | | Yes | No | Long Back | No |
| Kolaghat-WBPDCL | 4-6 | Static | ABB Unitrol 6800 | | PSS 2B | Dual | Yes | No | All Unit : 2014 | No |
| Sagardighi-WBPDCL | 1,2 | Static | ABB Unitrol 5000 | | | | No | No | | No |
| Sagardighi-WBPDCL | 3,4 | Brushless | BHEL | | PSS 3B | | Yes | Yes | Step Test on Unit 3 in 2018 and Unit 4 not done | No |
| Santhaldih-WBPDCL | 5,6 | Brushless | BHEL | AC3A | PSS 3B | | | Unit 5 in 2013 and Unit 6 is not Tuned | | No |
| Bandel-WBPDCL | 5 | Static | BHEL | | | | | No | | No |
| Bakreshwar-WBPDCL | 1 | Brushless | BHEL-Unitrol | | PSS-3B | | Yes | No | | No |
| Bakreshwar-WBPDCL | 2,3 | Brushless | BHEL-THYRISIEM-04 | | | | Yes | No | | No |
| Bakreshwar-WBPDCL | 4,5 | Brushless | BHEL-Unitrol | | PSS-3B | | Yes | No | | No |
| DPL | 7 | Static (through Carbon Brush) | Unitrol F 5000<br>ABB | ST1 | PSS 2A | Dual | No | No | N.A | Not App |
| DPL | 8 | Brushless | WBS NO CE/0800-SH8-48-01<br>BHEL | ---- | UN0662 | Dual | Yes | No | No | Not App |
| PPSP Site | 1,2,3,4 | Thyristor | Digital | Not | Not | Single | Yes | No | No | Not App. |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | type, full bridge | AVRTOSATEX 100, Vendor-Toshiba | availa ble | availabl e | | | | | |
| TLDP III | 4 x 33 | | | | | | | | | |
| TLDP IV | 4 X 44 | | | | | | | | | |
| **CESC** | | | | | | | | | | |
| Budge Budge-CESC | 1, 2 | Static | R-R Industrial Controls Limited | | | Dual | Yes | Yes | 29.07.15 | Yes |
| Budge Budge-CESC | 3 | Static | BHEL | | | Dual | Yes | Yes | 28.02.10 | No |
| HEL-CESC | 1,2 | Static | Unitrol 5000 | ST1A | PSS-2A | Dual | Yes | Yes during Commissioni ng | 2015 | No |
| **DVC** | | | | | | | | | | |
| Bokaro -DVC | 500 MW | Brushless | | | | | Yes | No | | No |
| Bokaro | 3 X 210 MW | | | | | | | | | No |
| Mejia-DVC | 4 | STATIC | BHEL | | OTHER | Dual | Yes | Yes during Commissioni ng | | No |
| Mejia-DVC | 5,6 | Brushless | BHEL | | OTHER | Dual | Yes | Yes during Commissioni ng | | No |
| Mejia-DVC | 7,8 | Brushless | BHEL | | OTHER | Dual | | Yes | U7:2010; U8:2011 | No |
| Raghunathpur-DVC | 1,2 | Brushless | Unitrol F 5000 | ST1A | PSS2A | Dual | No | No | | Not App |
| Durgapur-DVC | 1,2 | Brushless | | | OTHER | Dual | Yes | Yes | U1: 2012 U2: 2013 | No |
| Koderma-DVC | 1,2 | Brushless | BHEL | | | Dual | Yes | Yes | | No |
| Waria | 4 | | | | | | | | | No |
| Chandrapura B | 2 X 250 MW | | | | | | | | | No |
| **ISGS** | | | | | | | | | | |
| Kahalgaon NTPC | 1,2,3 | Semi-Static | ABB 6800 | | | Dual | Yes | Yes | U1: Dec 2017; U2: Apr 2016; U3 : Sept 2016 | Yes |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Kahalgaon NTPC | 4 | Semi-Static | BHEL | | | Dual | Yes | Yes | U4: May 2015 | Yes |
| Kahalgaon NTPC | 5,6,7 | Brushless | BHEL | | | Dual | Yes | Yes | U 5 & 6 : Jan 2009; U7:July 2010 | Yes |
| Farakka NTPC | 1,2,3 | Static | BHEL | | | Dual | Yes | Yes | All units : Jan 2008 | No |
| Farakka NTPC | 4,5 | Brushless | Siemens | | | Dual | Yes | Yes | All units : Jan 2008 | No |
| Farakka NTPC | 6 | Brushless | BHEL | | | Dual | Yes | Yes | Jan 2011 | No |
| Talcher Stage 2 | 3,4,5,6 | Brushless | BHEL | | | Dual | Yes | Yes | | Yes |
| Talcher Stage 1 | 1,2 | | | | | | Yes | | | No |
| Nabinagar NPGC | 1 | | | | | | | | | |
| BRBCL | 1,2,3 | | | | | | | | | |
| KBUNL | 1,2,3,4 | | | | | | | | | |
| Teesta V | 1,2,3 | Static | ALSPA P320 Alstom | ST7B | PSS2A | Dual | Yes | Yes | 2008 | |
| Rangit | 3 x 20 | | | | | | | | | |
| **IPP** | | | | | | | | | | |
| Teesta-III | 1,2,3,4,5,6 | Static | Thyne 5 , ELIN | | PSS2A | Dual | Yes | Yes | 2017 | Not App |
| Jorethang | Unit No. 1,2 | Static Excitation System | ALSPA CONTOGEN V3 P320 AVR, VENDOR - ALSTOM | IEEE 421.5 | PSS2A | Dual | Yes | Yes | Sept. 2015 | Yes |
| Tashiding | 1,2 | With Brushes | Unitrol 6080 | | PSS2B | Dual | Yes | Yes | 16 Oct 2017 | Unit 2 Submitted |
| Chuzachen HEP | 1,2 | Static | P320 AVR, ALSTOM | **ST7B** | PSS2A | Dual | Yes | Yes | 26.04.2013 | Yes |
| Dikchu | 1,2 | Static | AC7B,ALSTOM | AC7B | PSS2A/2B | Dual | yes | yes | 11/02/2017 | - |
| Maithon Power Limited | 1,2 | Brushless | EAR 50/15-30/8-3 BHEL | ESST1A | BHEL EDN7470400281 | Dual | Yes | Yes | 2017 | - |
| ADHUNIK | 1,2 | Brushless | ST5B | IEEE 421.5 | PSS2B | Dual | YES | Yes | U-1 (21/1/13),U- | No |

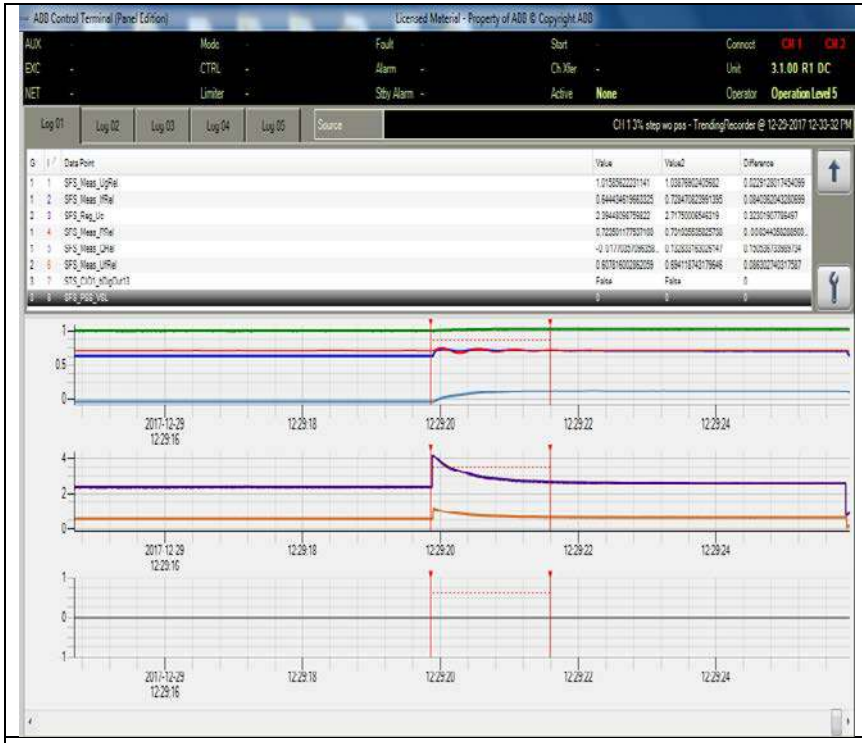
| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | 2(21/5/13) | |
| JITPL | 1,2 | Brushless | BHEL | | | Dual | Yes | Yes | 2016 : Both Units | Yes |
| GMR | | | | | | | | | | |
| **Orissa** | | | | | | | | | | |
| IB TPS | 1,2 | Static | Model: Unitrol 5, Vendor:BHEL | ST5B | PSS2B | Dual | Yes | Yes | Unit 1 May 2011 ; Unit 2 Jan 2012; Done during DAVR Commissioning | Not App |
| Upper Indravati | 1,2,3,4 | | | | | | | | | |
| Balimela | 6 X 60 | | | | | | | | | |
| Balimela | 2 X 75 | | | | | | | | | |
| Upper Kolab | 4 X 80 | | | | | | | | | |
| Rengali | 4 X 50 | | | | | | | | | |
| Sterlite | 4 X 600 | | | | | | | | | |
| **Jharkhand** | | | | | | | | | | |
| Tenughat | 1,2 | | | | | | | | | |
| Subarnrekha | 2 X 65 | | | | | | | | | |
| **Bhutan** | | | | | | | | | | |
| Tala | 6 X 170 | | | | | | | | | |
| Chukha | 4 X 84 | | | | | | | | | |

**Updated on: 31-01-19**

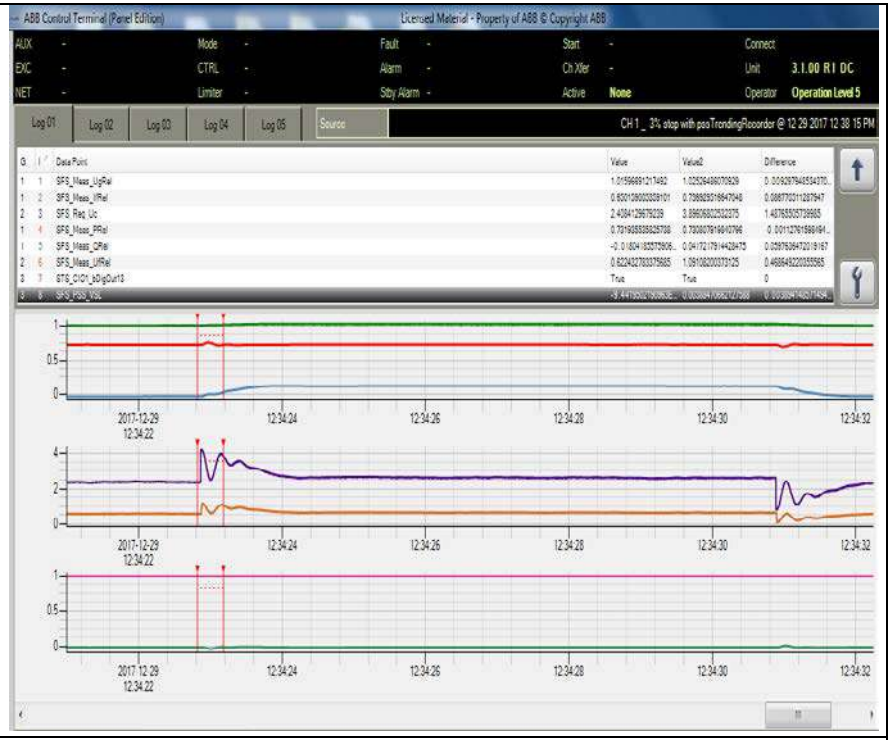
| Name of the Unit | Intra Plant Mode (Hz) | Step Size of $U_{ref}$ | Oscillation periodwith out PSS | Oscillation period with PSS | Whether PSS is effective as per step response test | Year of Tuning | Whether Recommended for Tuning |
|---|---|---|---|---|---|---|---|
| Kahalgaon Unit 1 | | 3 % | 3 cycle | 1 cycle | Yes | 2017 | Yes after Bus Split |
| Kahalgaon Unit 2 | 1.5 Hz | 3 % | 3 cycle | 1 cycle | Yes | 2016 | Yes after Bus Split |
| Kahalgaon Unit 3 | | 6 % | - | - | Provided picture not clear to analyze response | 2016 | To be decided after explanation by NTPC, Also after bus split, returning is required |
| Kahalgaon Unit 4 | 1.876 | 3 % | 5 cycle | 3 Cycle | Yes | 2015 | Yes after Bus Split |
| Kahalgaon Unit 5 | | 4 % | | | No Appreciable Response | 2009 | To be decided after explanation by NTPC, Yes after Bus Split |
| Kahalgaon Unit 6 | | 4 % | | | No Appreciable Response | 2019 | |
| Kahalgaon Unit 7 | | 2 % | | | Provided picture not clear to analyze response | 2010 | |
| Teesta V Unit 1 | | 2 % | 5 cycle | 2 cycle | Yes | 2008 | Yes in view of changes in network |
| Teesta V Unit 2 | | 2 % | 5 cycle | 1 cycle | Yes | 2008 | |
| Teesta V Unit 3 | | 2 % | 5 cycle | 1 cycle | Yes | 2008 | |
| Talcher Unit 3 | | 3 % | - | - | PSS is showing response but active power plant is not providing appreciable change. | | NTPC may explain the details after which requirement of retuning to be decided. |
| Talcher Unit 6 | | 3 % | 3 cycle | 2 cycle | Yes | | |
| Budge Budge 1 | | 2 % | 5 cycle | 1 cycle | Yes (Tuned for various contingency) | 2015 | No |
| Budge Budge 2 | | 2 % | 5 cycle | 1 cycle | Yes (Tuned for various contingency) | 2015 | No |
| JITPL Unit 1 | | 5 % | - | - | No Appreciable Response | 2016 | JITPL to explain the response based on which it will be decided. |
| JITPL Unit 2 | | 5 % | - | - | No Appreciable Response | 2016 | |
| Chujachen Unit 1 | | 2 % | 6 cycle | 1 cycle | Yes | 2013 | Yes in view of changes in network |
| Chujachen Unit 1 | | 2 % | 6 cycle | 1 cycle | Yes | 2013 | |
| Tashiding Unit 2 | 1.5 Hz | 4 % | 5 Cycle | 1 Cycle | Yes | 2017 | Yes in view of changes in network |

**Annexure Plots:**

## 1. Kahalgaon Unit 1

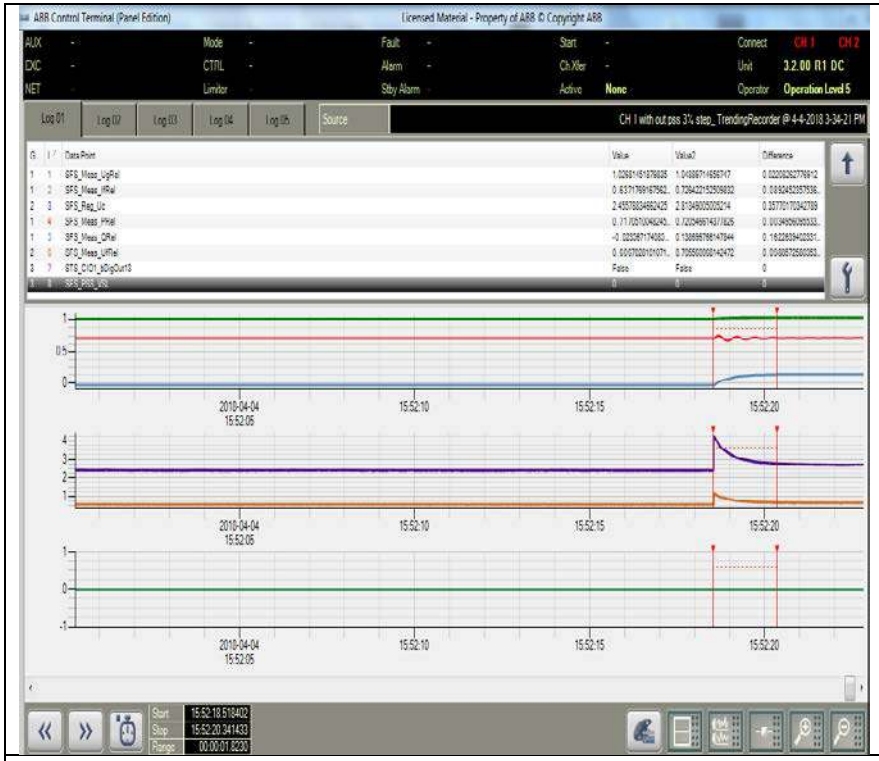



**Without PSS**

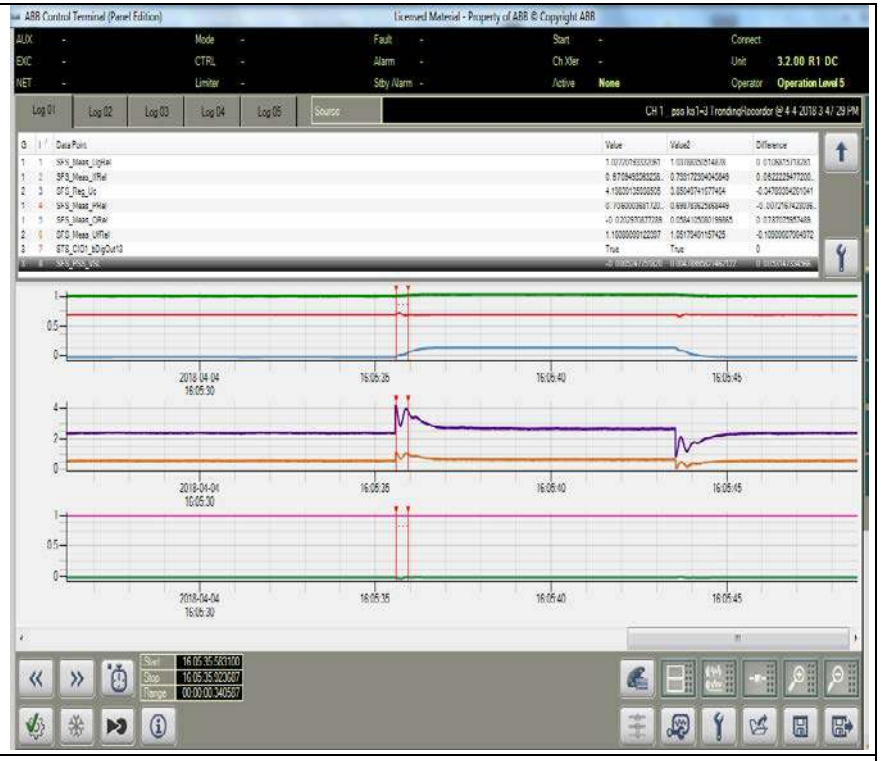



**With PSS**

## 2. Kahalgaon Unit 2

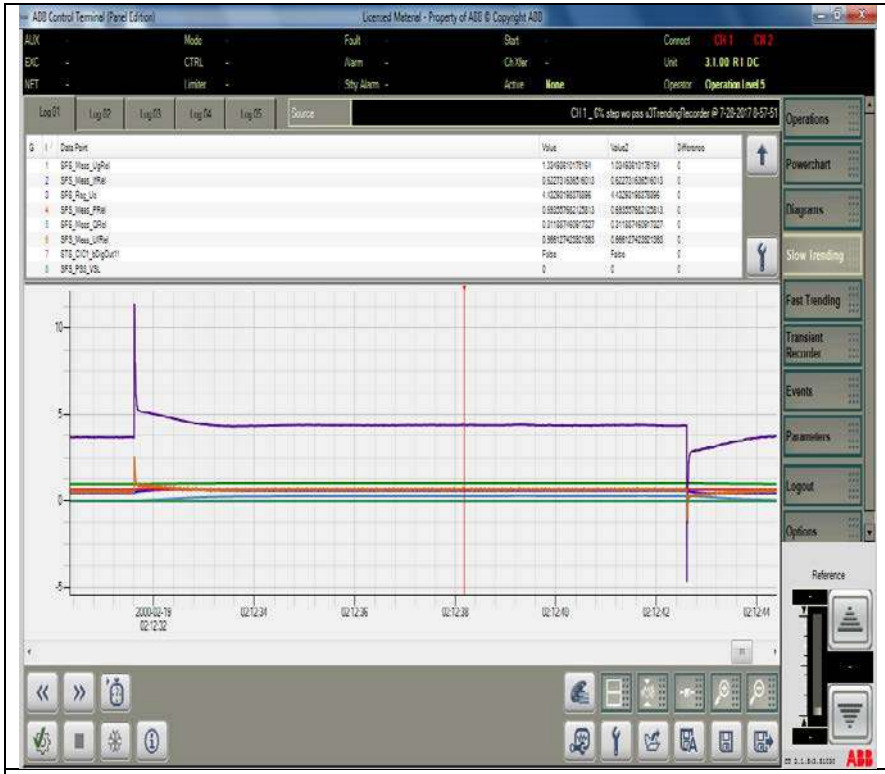



**Without PSS**

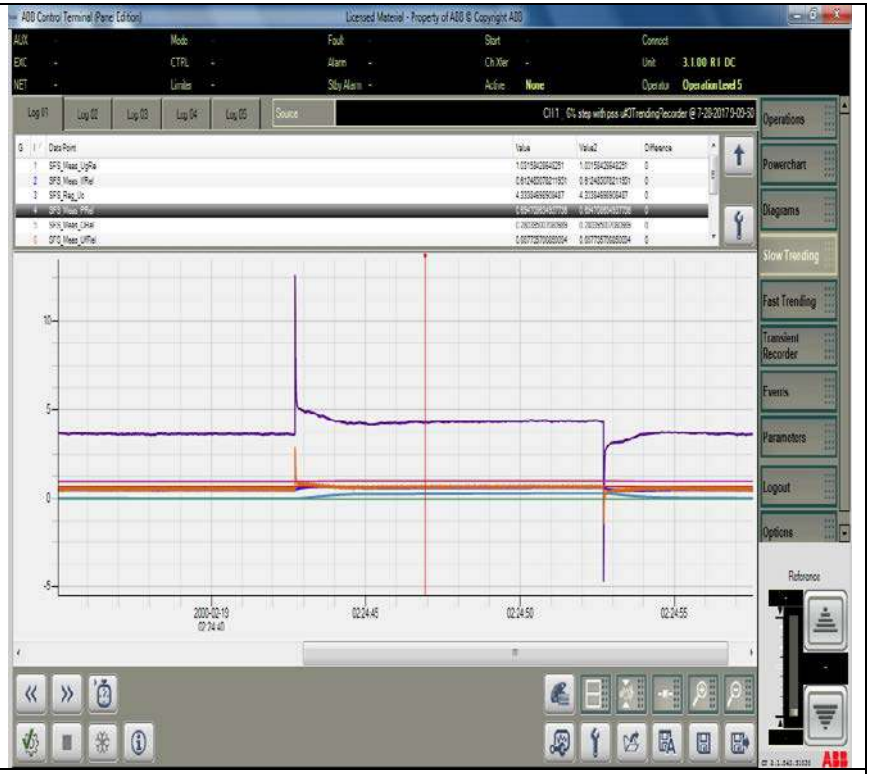



**With PSS**

## 3. Kahalgaon Unit 3

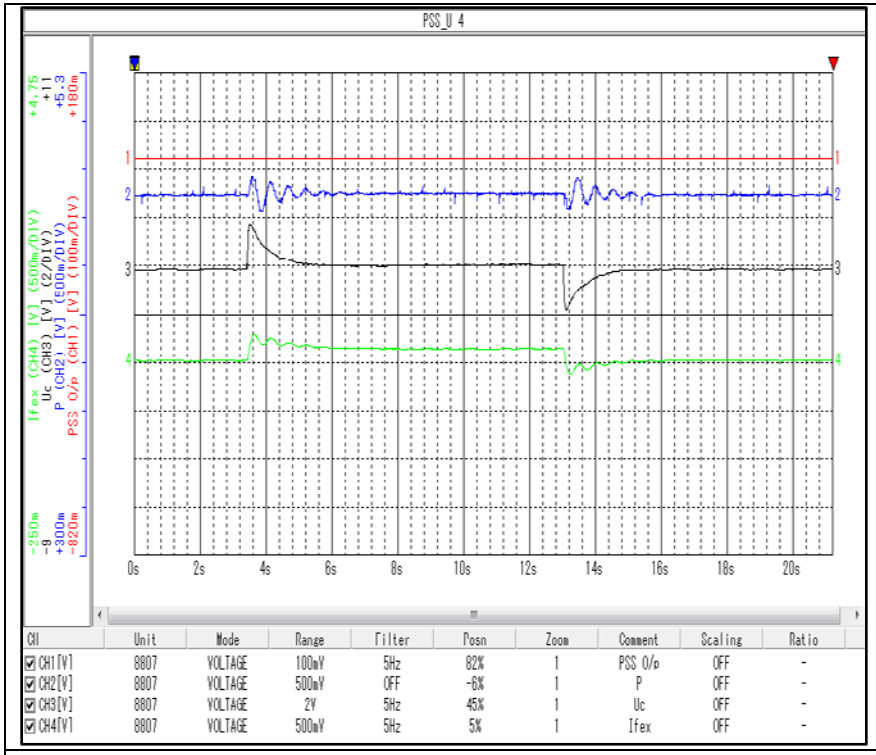



**Without PSS**

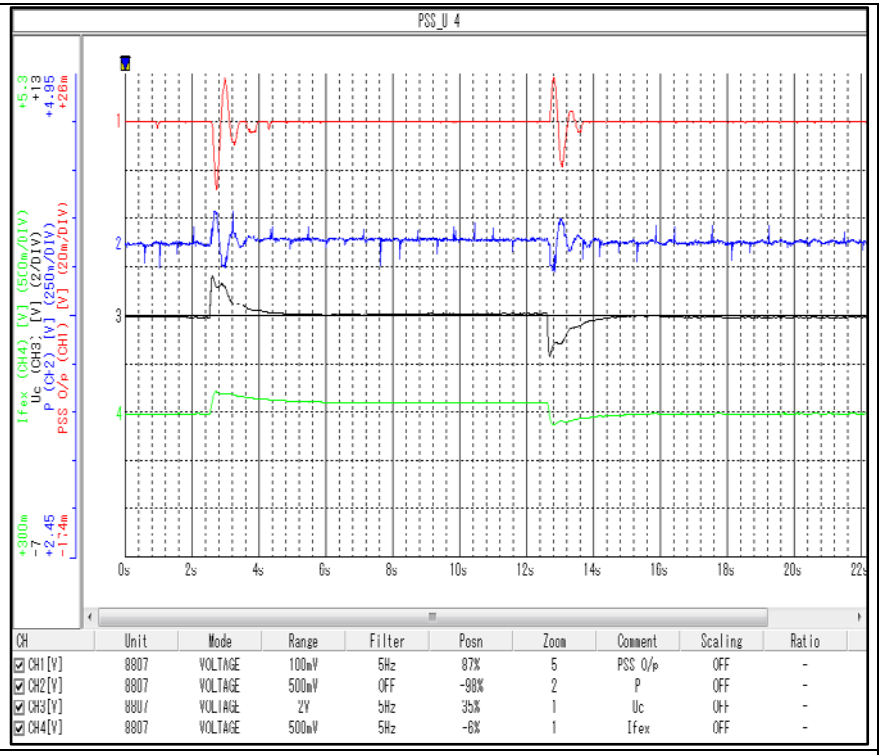



**With PSS**

## 4. Kahalgaon Unit 4

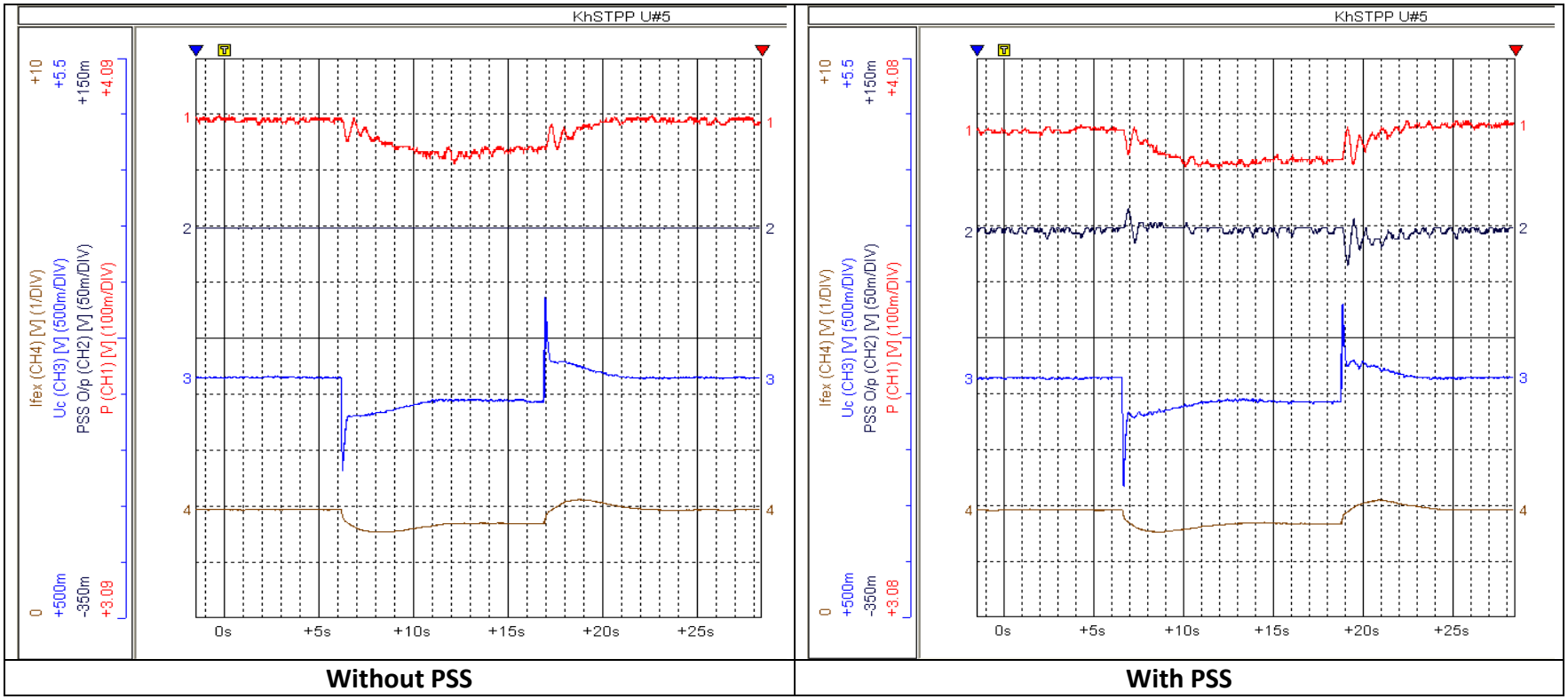



**Without PSS**



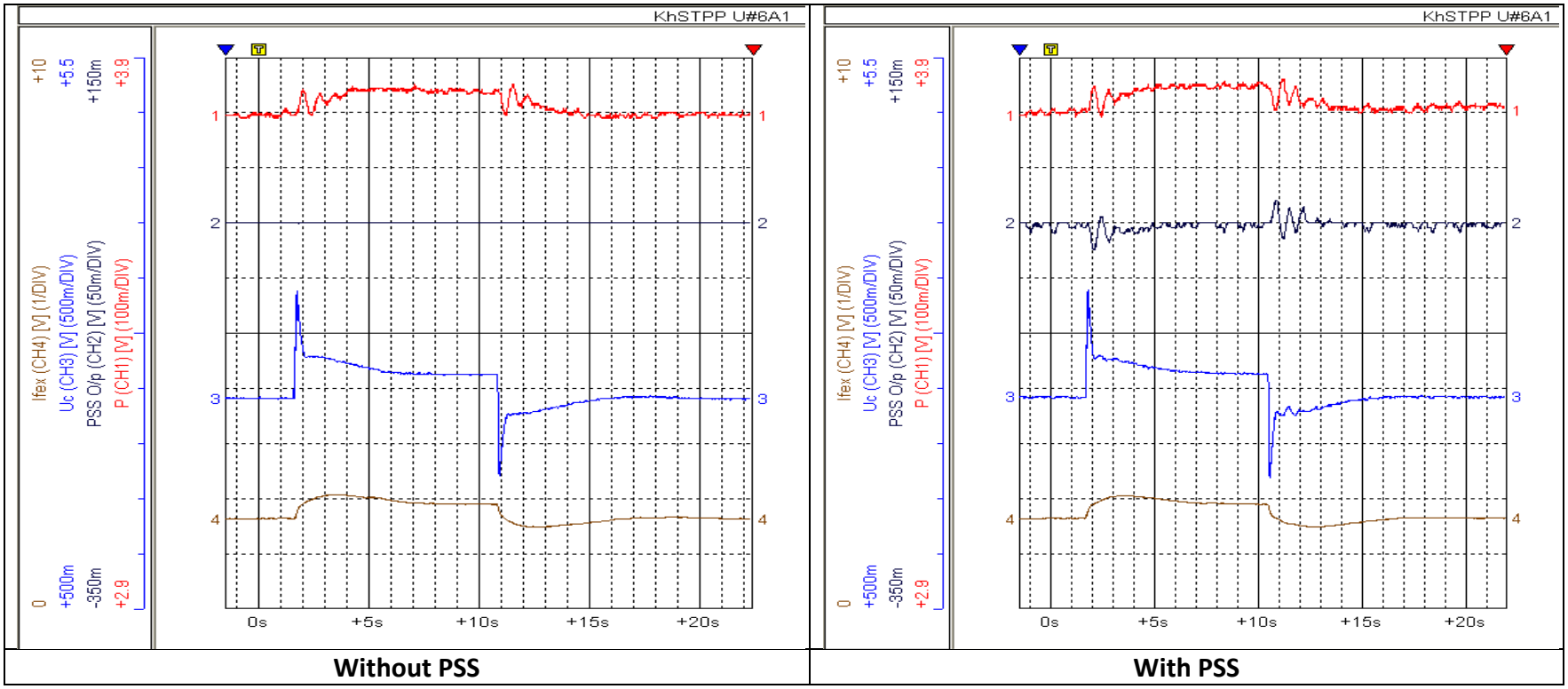

**With PSS**

## 5. Kahalgaon Unit 5



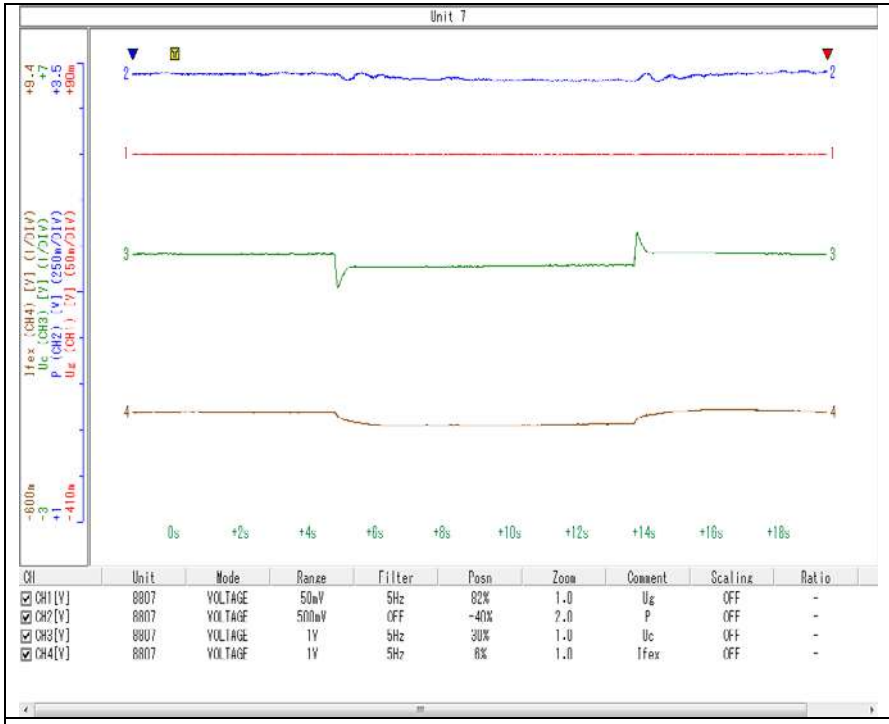

| Without PSS | With PSS |
|---|---|

## 6. Kahalgaon Unit 6

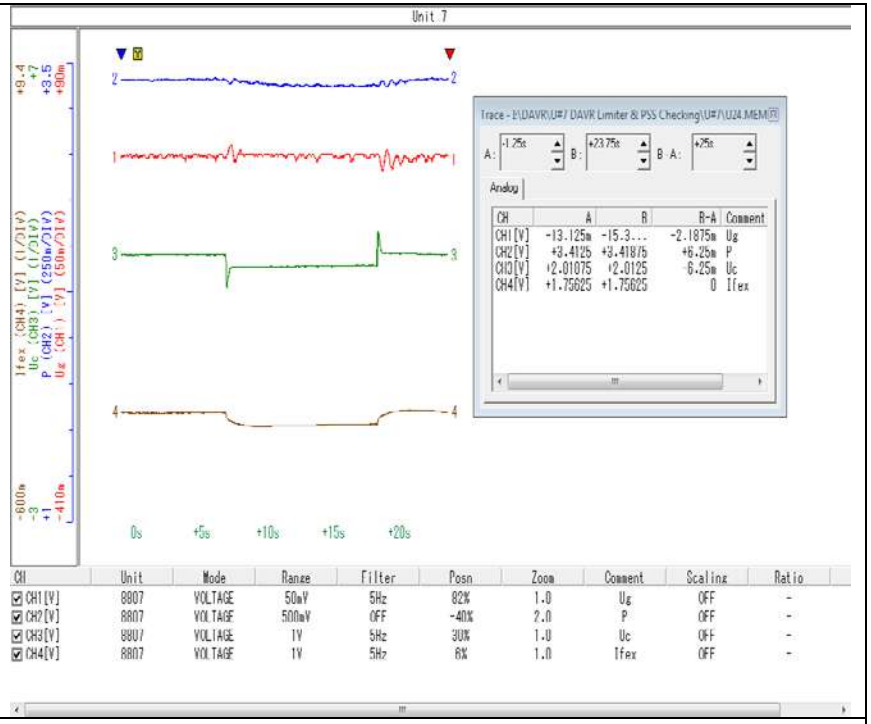



| Without PSS | With PSS |
|---|---|

## 7. Kahalgaon Unit 7

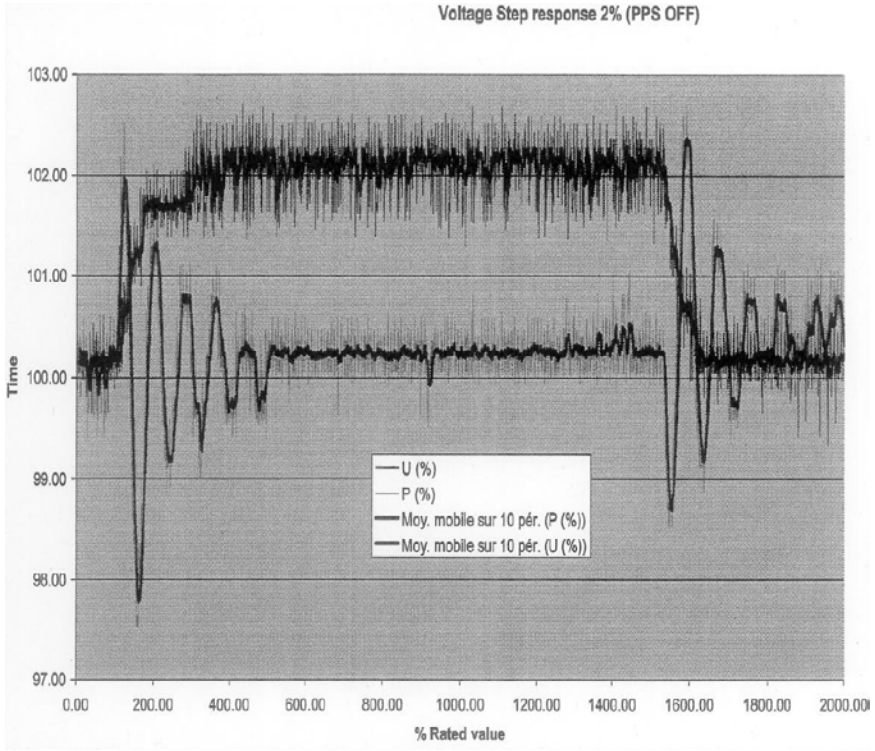


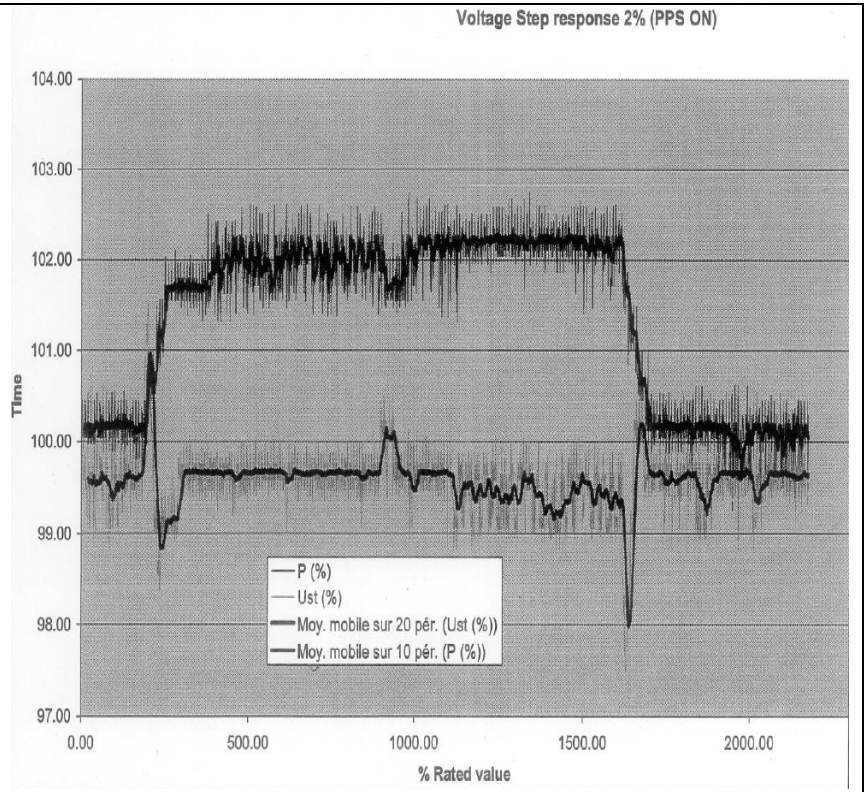

**Without PSS**




**With PSS**

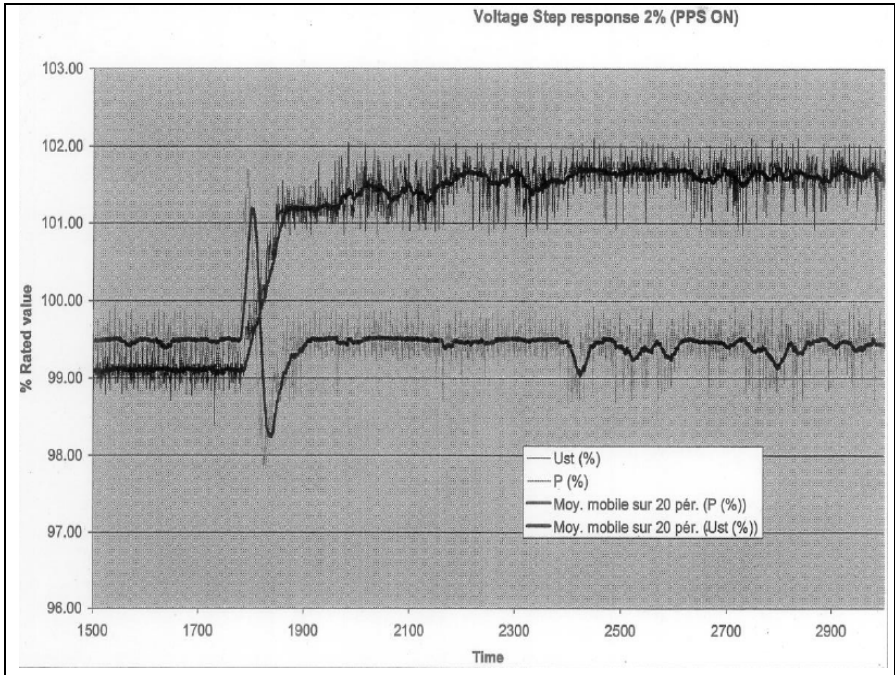
## 8. Teesta V Unit 1



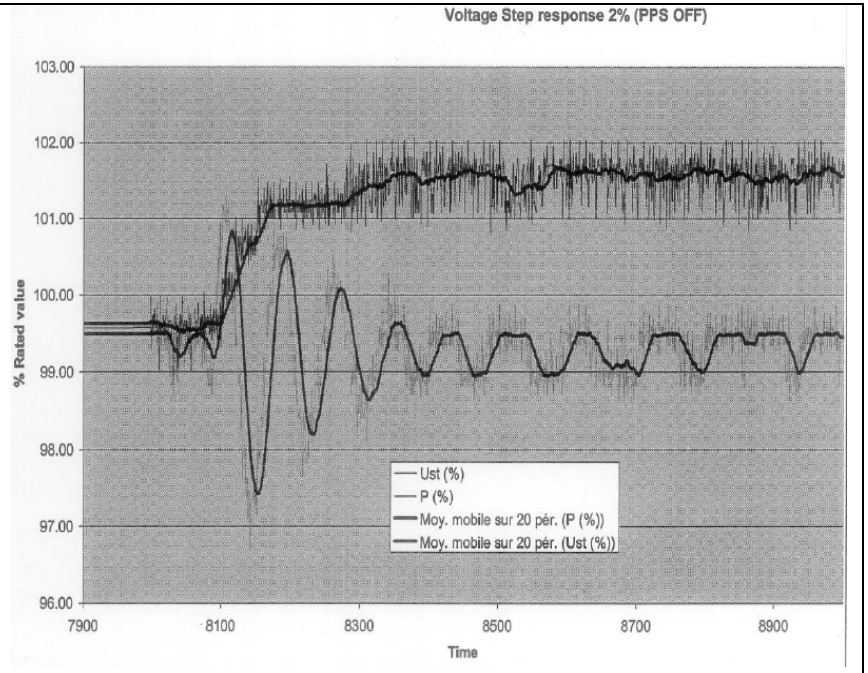




| Without PSS | With PSS |
|---|---|

## 9. Teesta V Unit 2

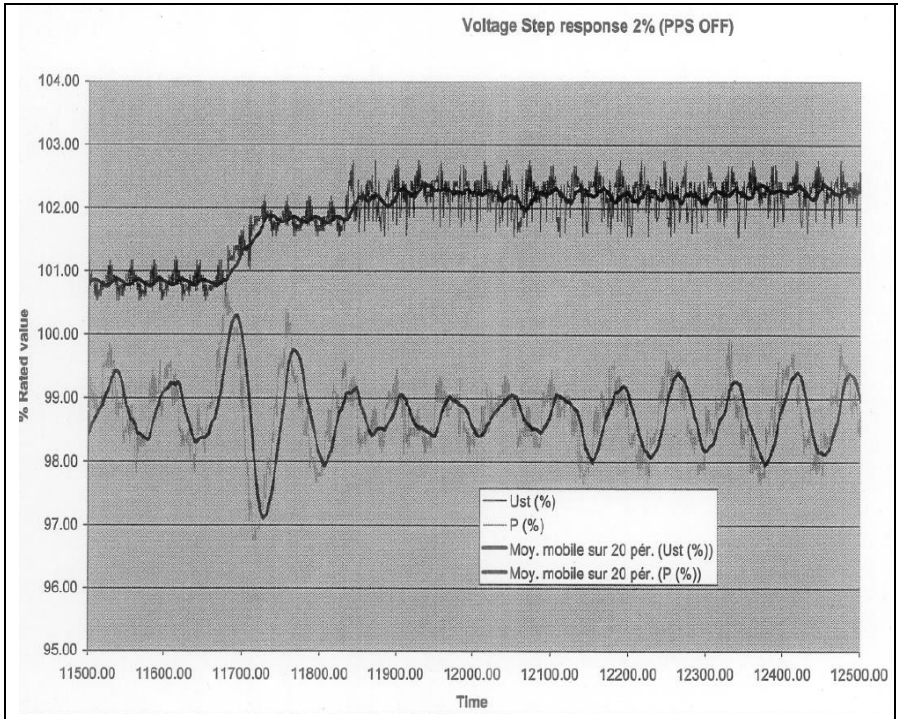



**Without PSS**

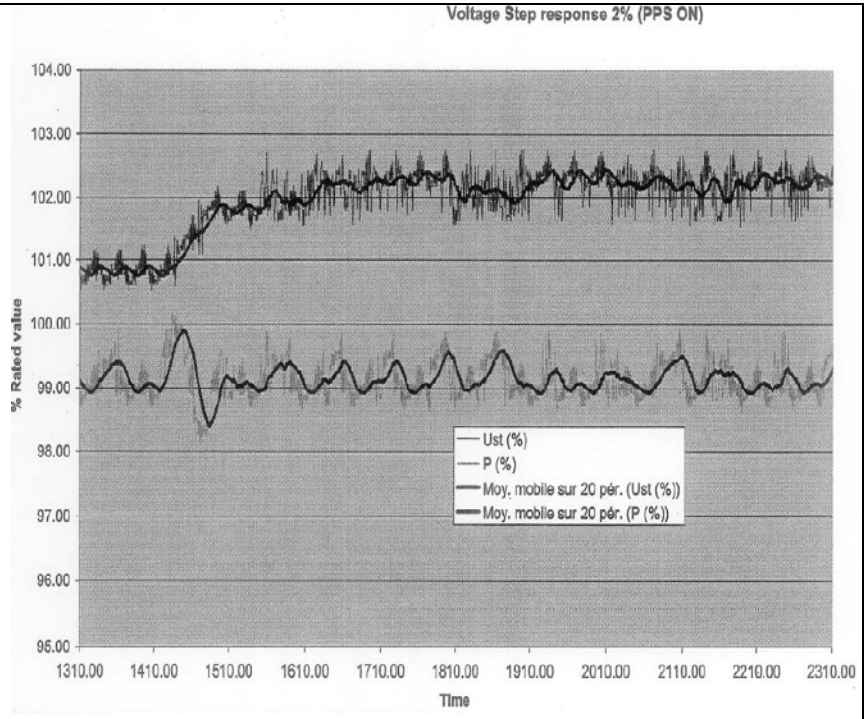



**With PSS**

## 10. Teesta V Unit 3

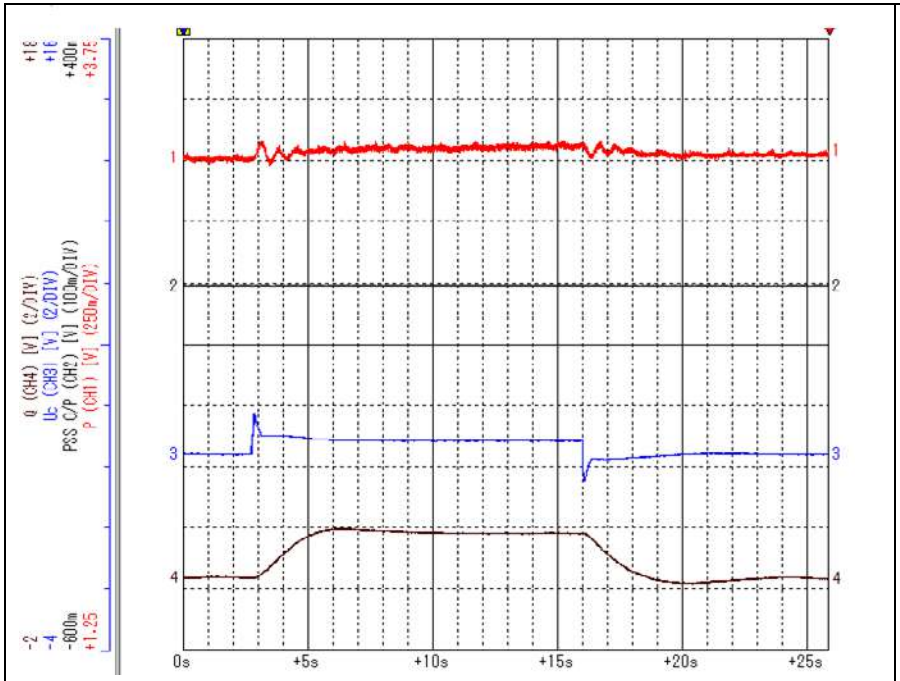



Without PSS

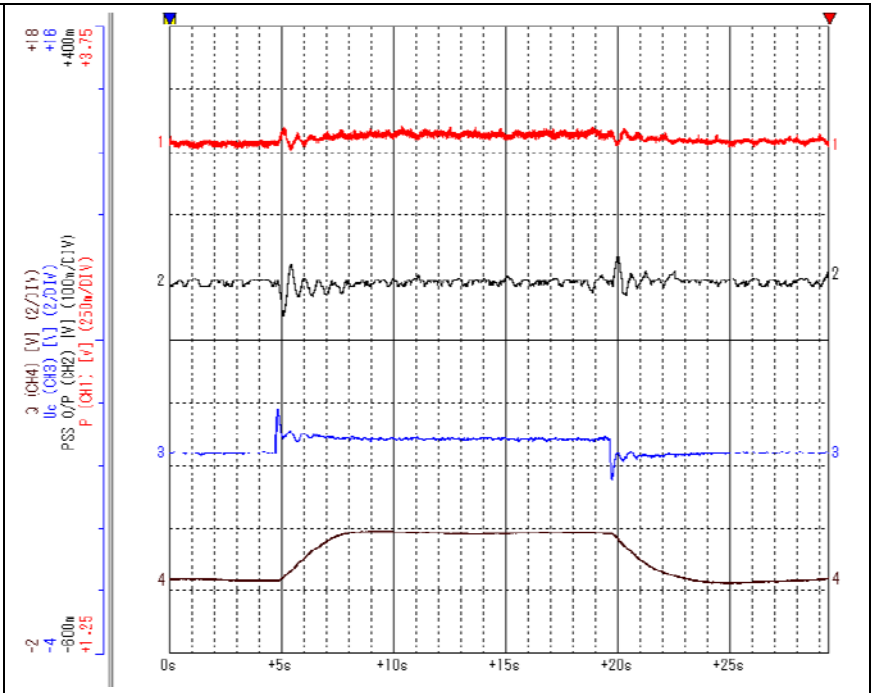



With PSS

## 11. Talcher Stage 2 Unit 3

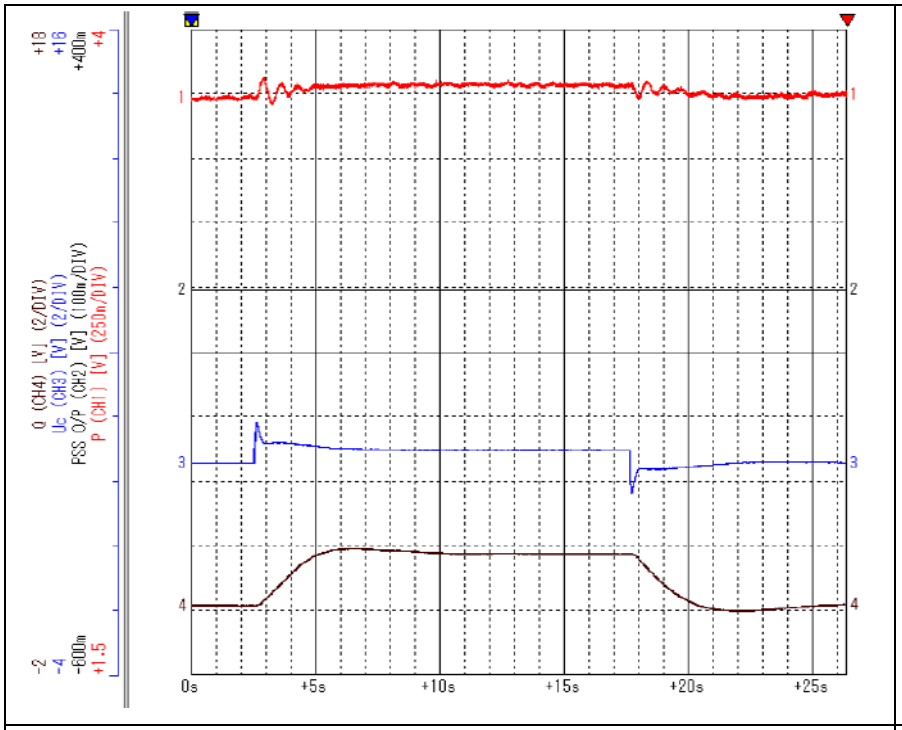



**Without PSS**

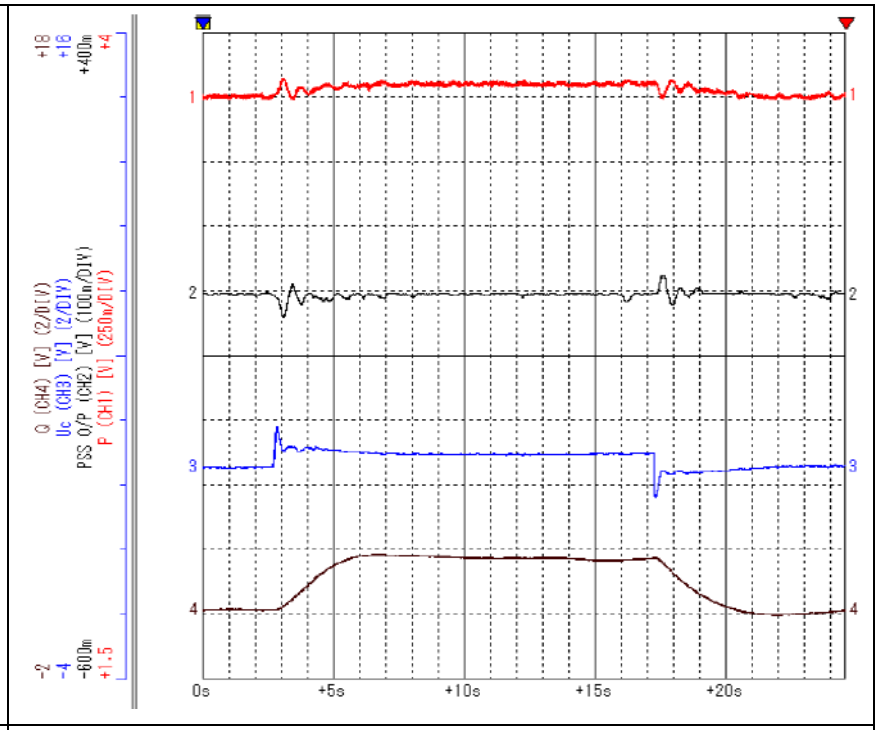



**With PSS**

## 12. Talcher Stage 2 Unit 6

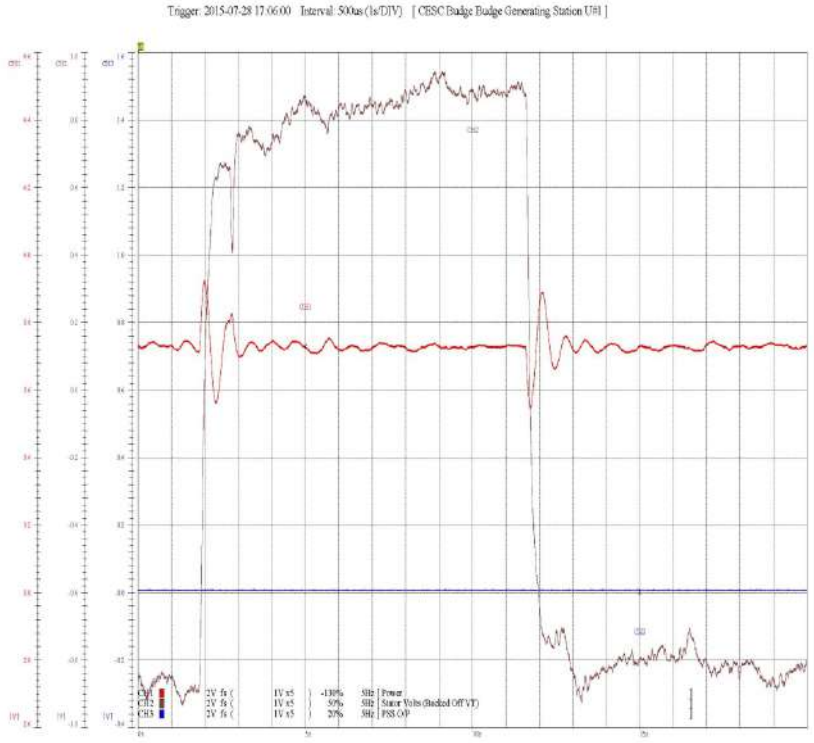
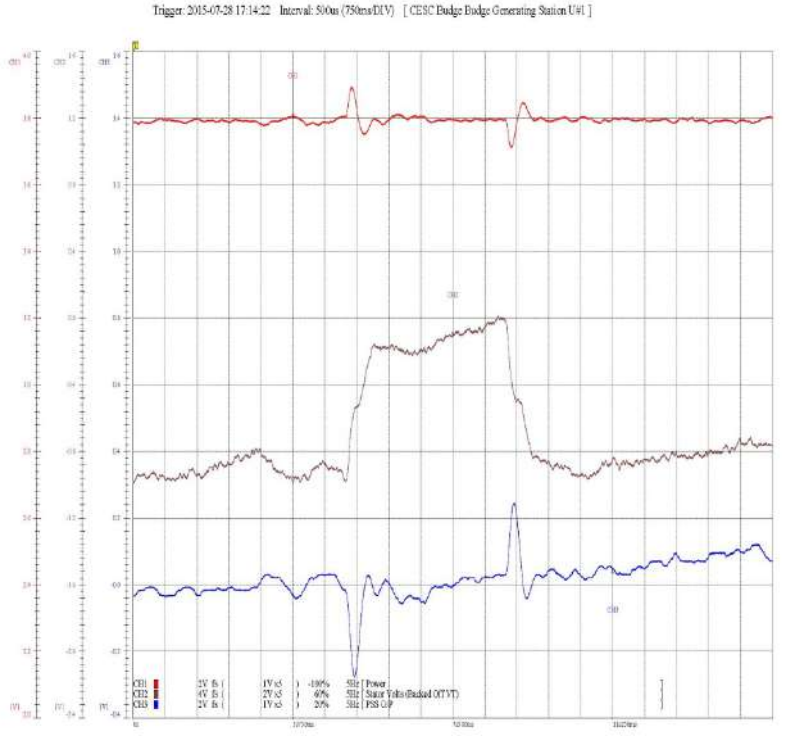



**Without PSS**

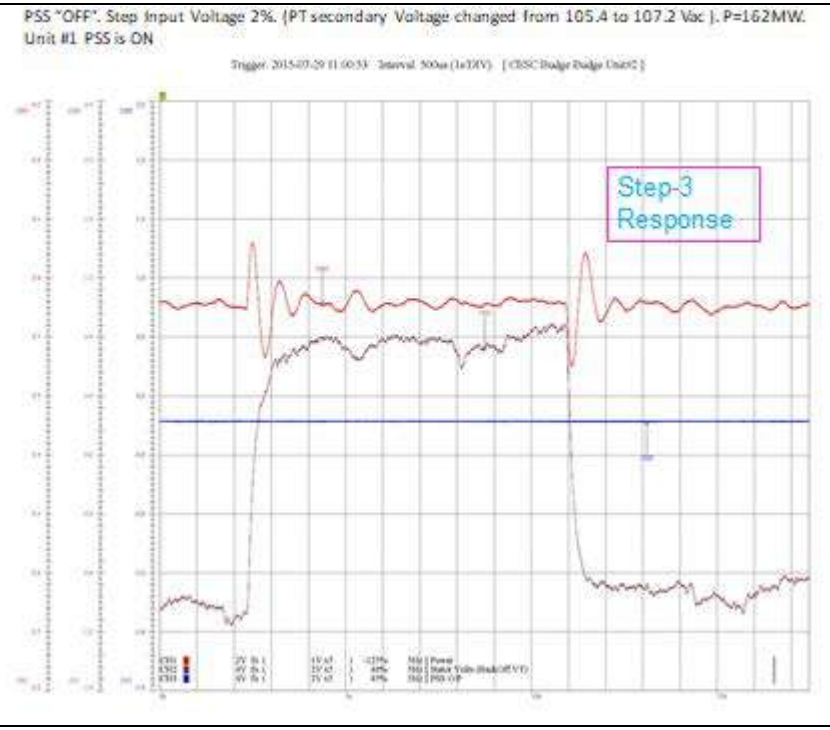
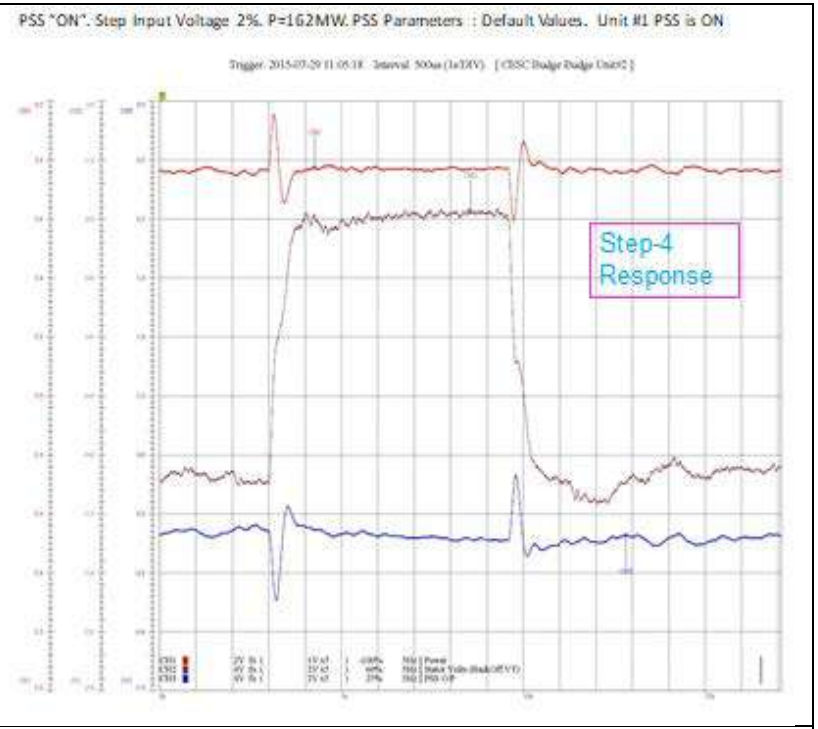



**With PSS**

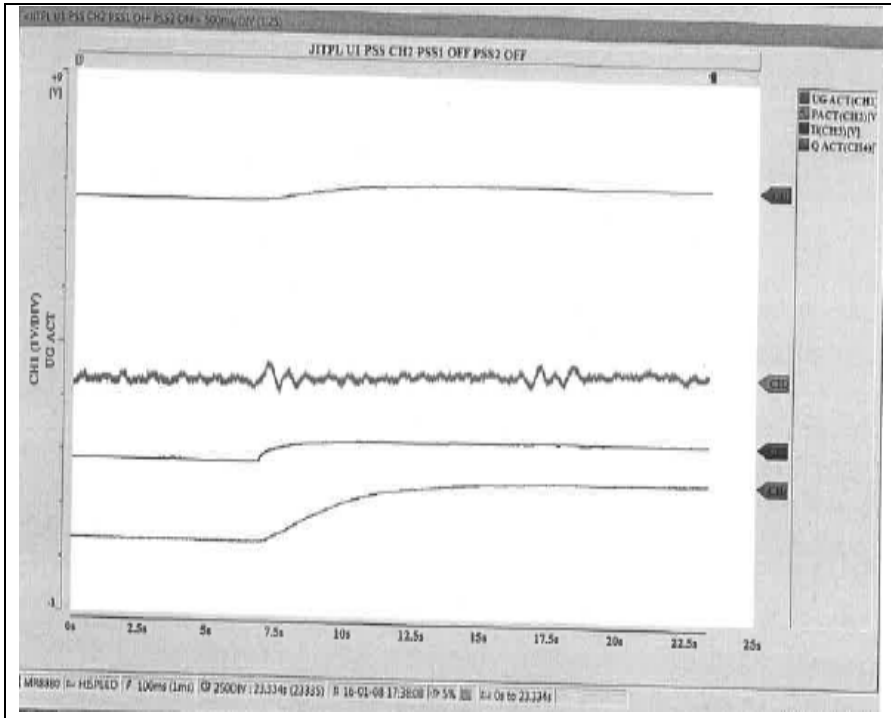
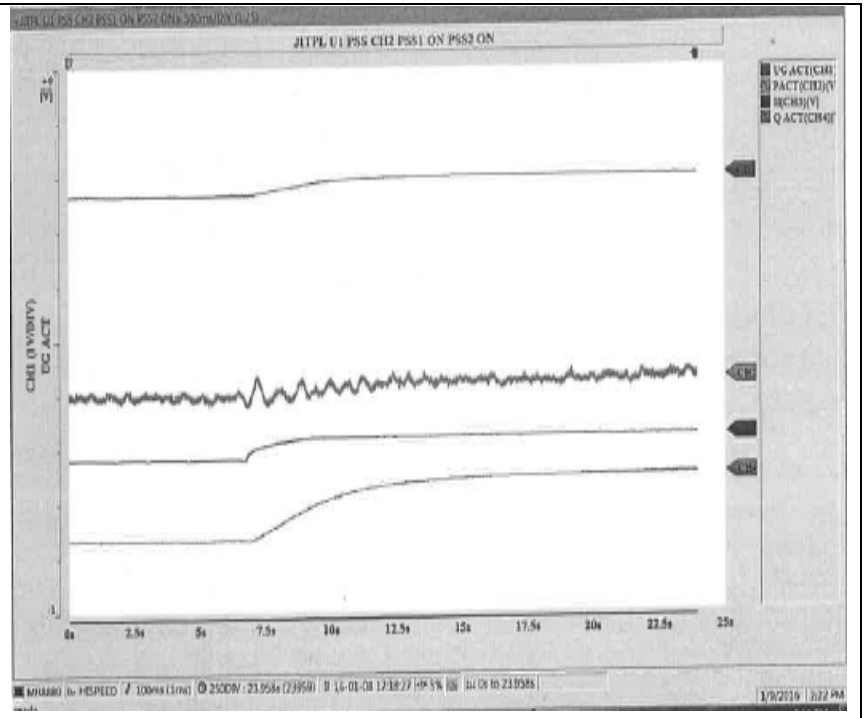
## 13. Budge Budge Unit 1

| | |
|---|---|
|  |  |
| **Without PSS** | **With PSS** |

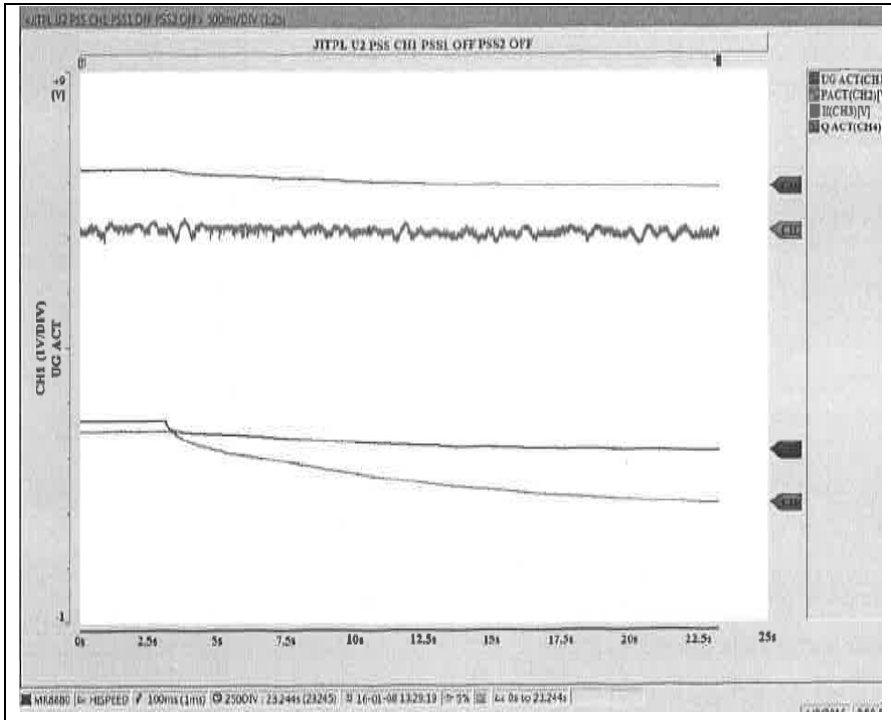
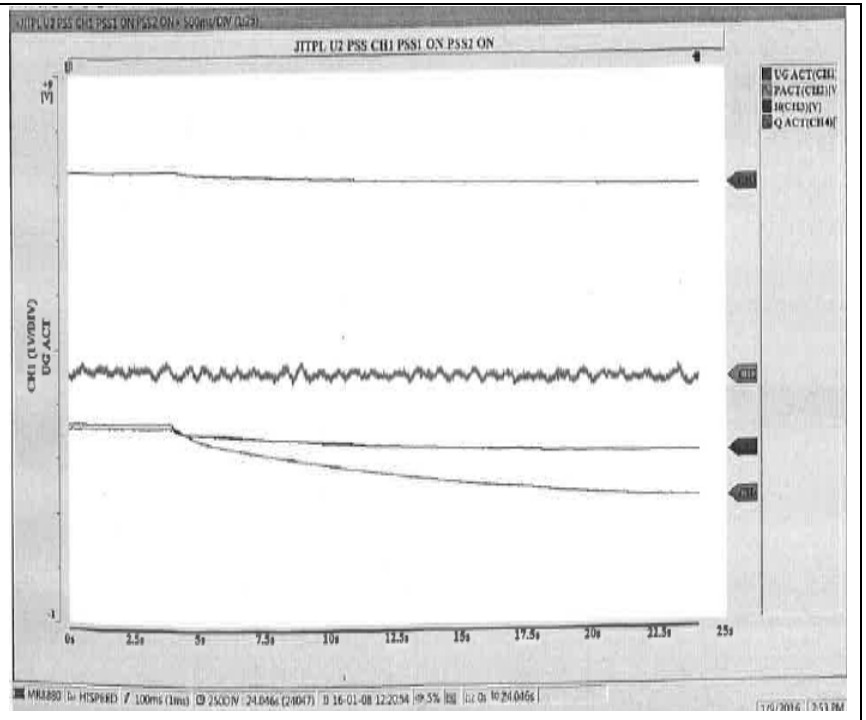
## 14. Budge Budge Unit 2

| | |
|---|---|
|  |  |
| **Without PSS** | **With PSS** |

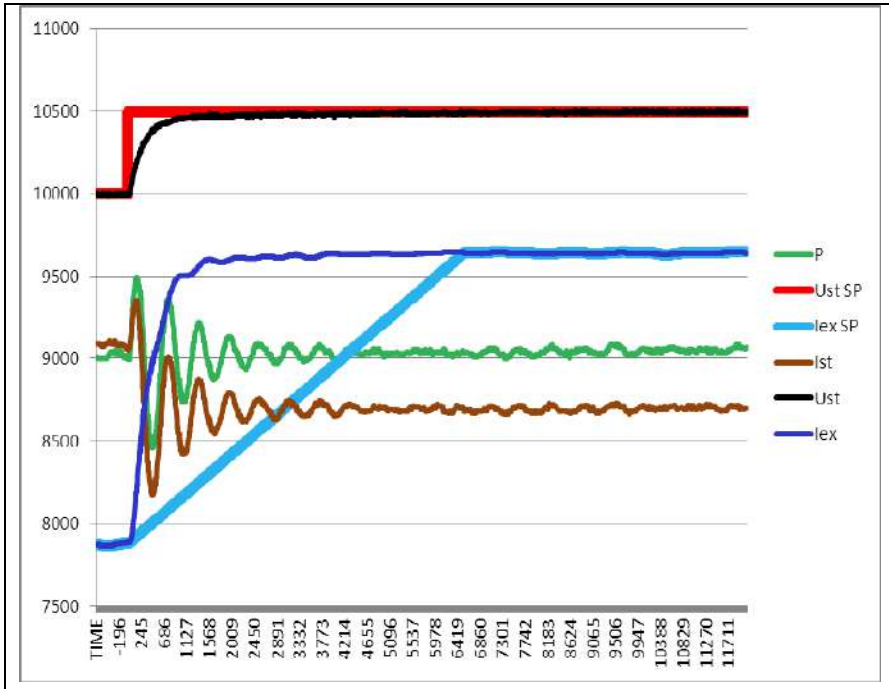
**15. JITPL Unit 1**

| | |
|---|---|
|   |   |
| **Without PSS** | **With PSS** |

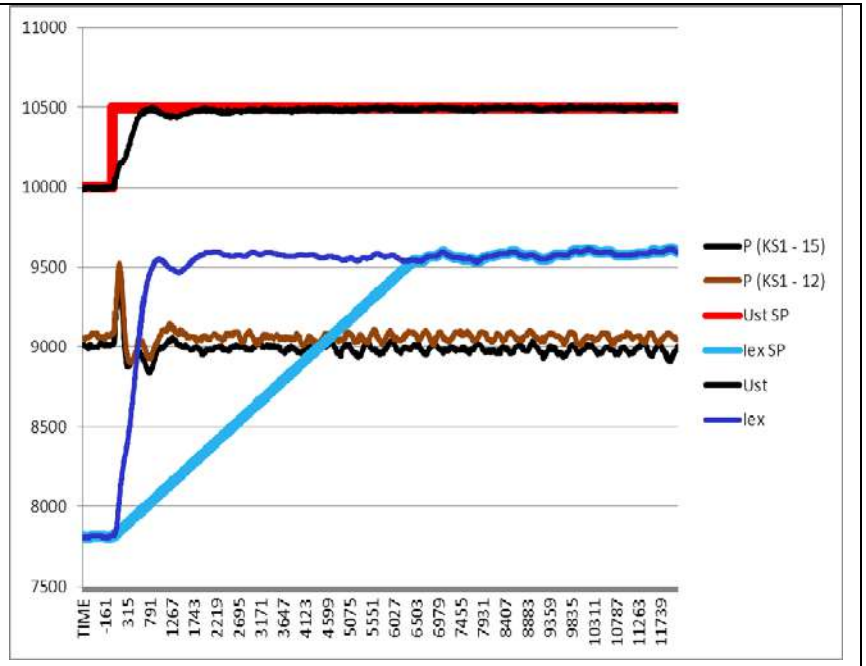
**16. JITPL Unit 2**

| | |
|---|---|
|  |  |
| **Without PSS** | **With PSS** |

**17. Chujachen Unit 1**

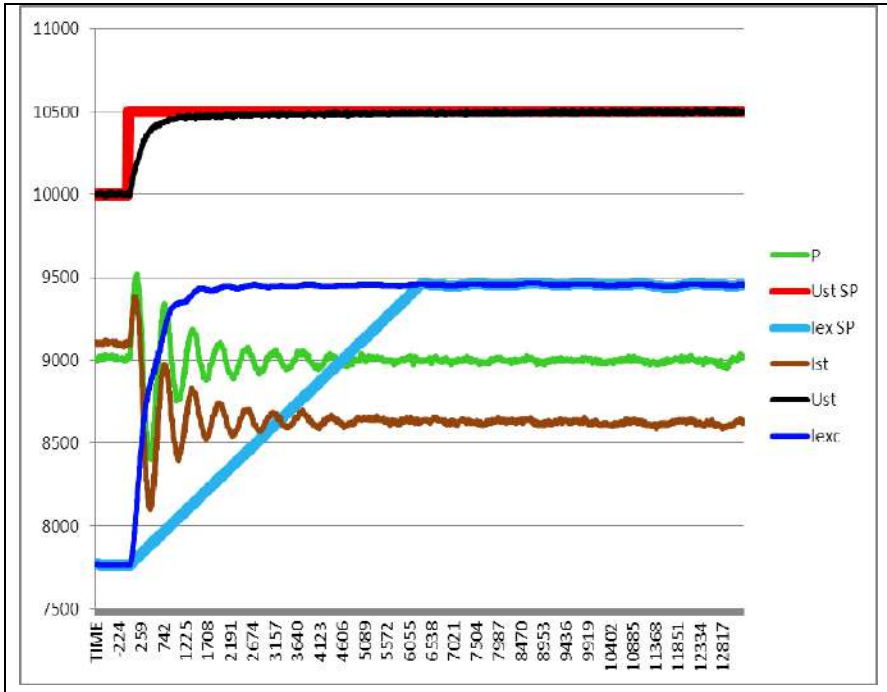



**Without PSS**

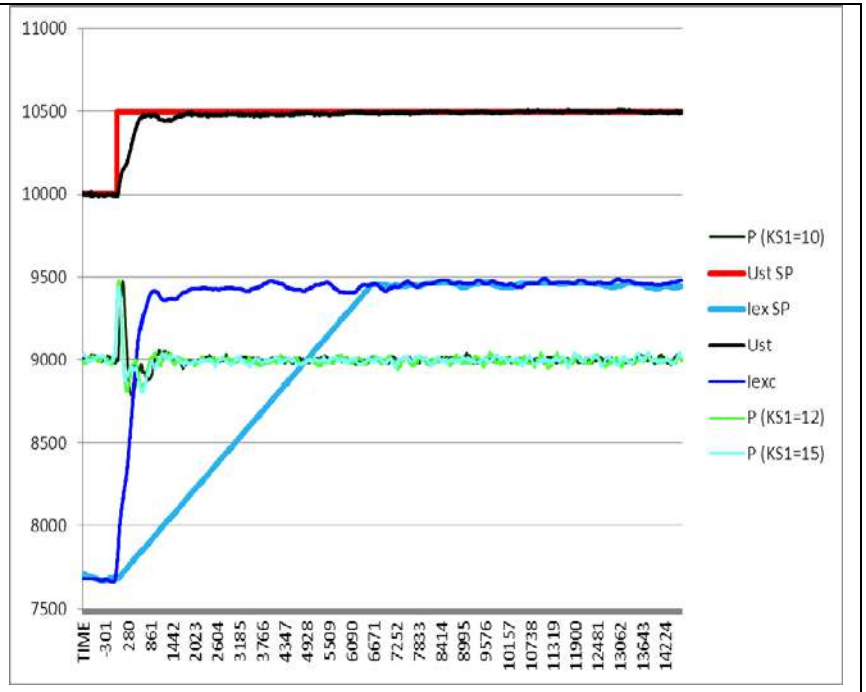



**With PSS**

**18. Chujachen Unit 2**

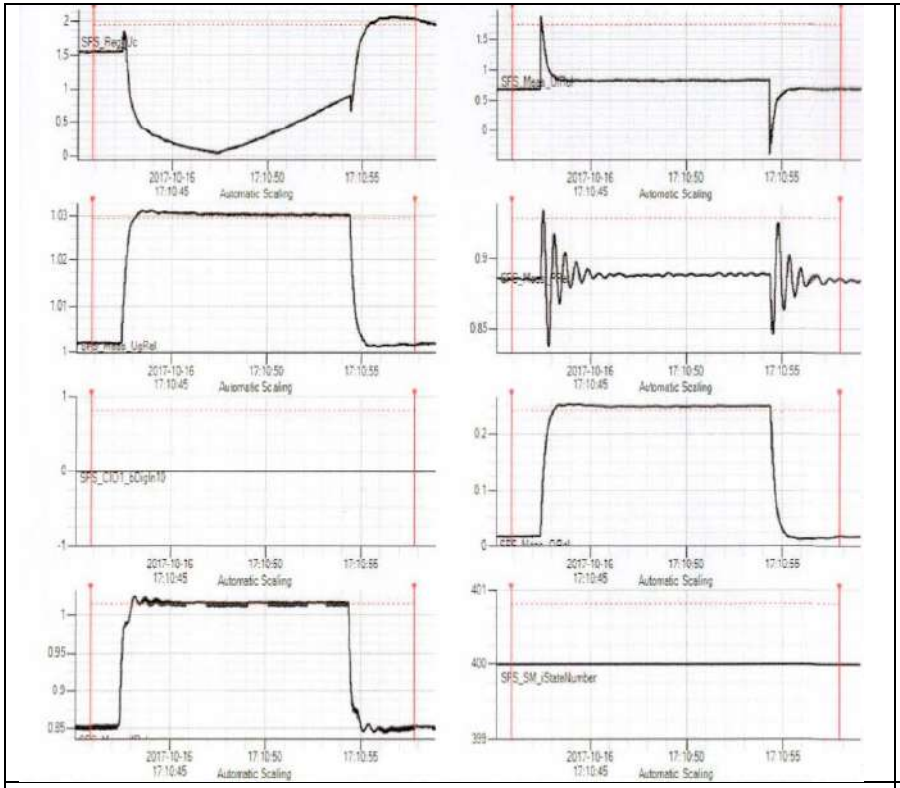



**Without PSS**

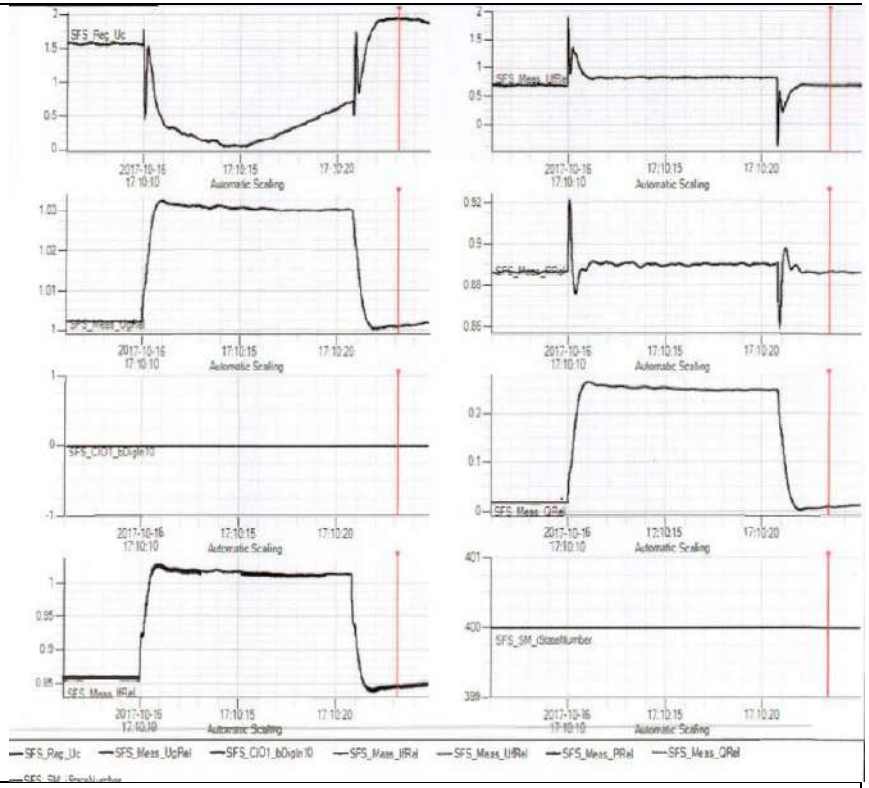



**With PSS**

**19. Tashiding Unit 2**




**Without PSS**




**With PSS**